Bureau of Standards
FEB 2 0 1929

Vol. 1. No. 5. JANUARY, 1921

THE ENGLISH ELECTRIC JOURNAL

Published by
THE ENGLISH ELECTRIC COMPANY
LTD.

The English Electric Company Limited.

Directors:

SIR CHARLES ELLIS, G.B.E., K.C.B., (*Chairman*)
W. L. HICHENS (*Deputy Chairman*)
SIR JOHN A. F. ASPINALL, M.INST.C.E.
CLAUD T. CAYLEY
BERNARD A. FIRTH
SIR ALEX. GRACIE, K.B.E., M.V.O.
LT.-COL. SIR JOHN H. MANSELL, K.B.E., D.L.
LORD MESTON, K.C.S.I.
JOHN SAMPSON, C.B.E., M.INST.C.E.

Joint Managing Directors:

P. J. PYBUS, C.B.E.
W. RUTHERFORD

Secretary: E. D. JOHNSON, A.C.A.

Chief Accountant: J. B. BRENT, A.C.A.

Engineer-in-Chief: EVAN PARRY, B.SC., M.INST.C.E., M.I.E.E.

Executive Committee:—

W. L. HICHENS (*Chairman*)
LORD MESTON, K.C.S.I.
LT-COL. SIR JOHN H. MANSELL, K.B.E., D.L.
P. J. PYBUS, C.B.E.
W. RUTHERFORD.

Sales and Contracts Committee:—

W. RUTHERFORD (*Chairman*)
V. WATLINGTON, A.C.G.I., M.I.E.E. (*Vice-Chairman*)
E. G. FLEMING, M.I.E.E.
J. GORDON, A.M.I.MECH.E.
M. J. D. KERR, M.A.
E. M. MALEK, M.I.E.E.
H. E. MIDGLEY, M.A., M.INST.C.E., M.I.E.E., M.I.MECH.E.
H. T. RICE
F. WALLIS, M.A., M.I.E.E.

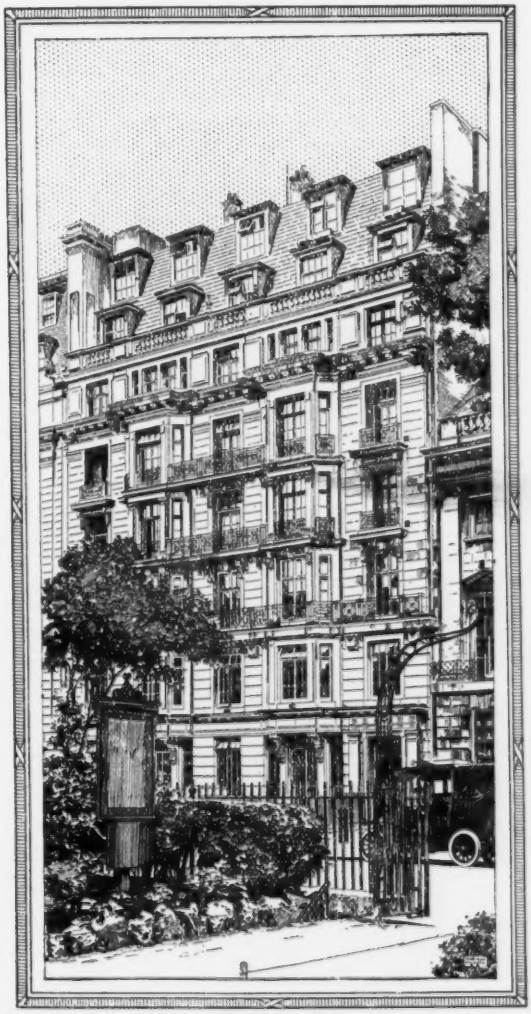
Central Works Committee:—

P. J. PYBUS, C.B.E. (*Chairman*)
A. F. BENNETT, M.INST.C.E., M.I.N.A.
J. CONNER, M.B.E., M.I.E.E., M.I.MECH.E.
J. C. CRAWSHAW.
C. HARDIE, D.S.O., A.M.I.E.E.
H. F. HEMMINGS, M.I.MECH.E., M.I.A.E.
R. LIVINGSTONE, A.M.I.E.E.
W. L. MARSHALL
W. PARKER
C. W. PARKER
A. H. STURDEE, M.B.E.

Works:

ORDNANCE WORKS, Coventry.
DICK, KERR WORKS, Preston.
PHOENIX WORKS, Bradford.
SIEMENS WORKS, Stafford.
WILLANS WORKS, Rugby.

The ENGLISH ELECTRIC JOURNAL



Queen's House from Lincoln's Inn Fields.

All rights of republication, including translation of articles, are reserved.

General View of Willans Works, Rugby.

The English Electric Journal

Vol. 1. No. 5. JANUARY, 1921. One Shilling.

CONTENTS.

	PAGE
QUARTERLY NOTES - - -	167
THE WILLANS WORKS, RUGBY -	170
THE GOVERNING OF STEAM TURBINES - - - -	178
ELECTRICITY IN THE TINPLATE INDUSTRY - - - -	190
FUSES - - - - - -	199
THE COOLING OF WATER IN A CANAL - - - -	210

EDITORIAL.

All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2.

QUARTERLY NOTES.

It is now twelve months since the first number of this journal appeared. Much progress has been made during that period in the consolidation and extension of the business of the English Electric Company, and the moment is opportune for a brief review of what has been accomplished.

The Company, as we explained a year ago in the introduction to our first issue, controls and operates under one management :

The Dick, Kerr Works, Preston,
The Ordnance Works, Coventry,
The Phœnix Works, Bradford,
The Siemens Works, Stafford, and
The Willans Works, Rugby.

All these are well-known names in the engineering industry, and four of them were pioneers in different branches of electrical manufacture.

During the last twelve months the Company has arranged certain important associations both at home and abroad, which materially strengthen and consolidate its position. We take the opportunity of mentioning some of them here.

Siemens Bros. & Co., Limited.—There is a working arrangement which gives preferential supply of cables and

apparatus that may be required in carrying out comprehensive contracts.

English Electric & Siemens Supplies, Limited.—This is jointly controlled by the English Electric Company and Siemens Bros. for the marketing of the supply products of the two companies.

Consolidated Construction Co., Limited. — The general contracting departments of Dick, Kerr & Co. and J. G. White & Co. have been amalgamated under this name, and the combined experience of their staffs is available for dealing with complete installations of steam or hydraulic plants, power transmission lines and electric railway equipment.

Les Constuctions Electriques de France and Les Constructions Electriques de Belgique, each with a capital of 40 million francs, are in close association with each other and with the English Electric Company, and occupy an important position in the electrical industry of Western and Southern Europe. They hold the manufacturing rights of the English Electric Company for France and Belgium, and act as agents for that company, in France, Belgium, Italy, Luxembourg, Holland, Spain, Portugal and Poland, and in the Colonies and Dependencies of those countries.

Les Constructions Electriques de France have succeeded Les Constructions Electriques du Rhône, the former agents of Dick, Kerr & Co., Ltd. They have acquired the well-known Water Turbine business of Les Etablissements Singrun of Epinal. In addition to works near Lyons, now approaching completion, and laid out for the manufacture of tramway rolling stock, electric traction equipment and general electrical machinery, they are erecting new works at Tarbes, in the Pyrenees Province, specially designed for the manufacture of hydraulic turbines, electric locomotives, and heavy electrical machinery.

Les Constructions Electriques de Belgique have absorbed the Compagnie Internationale d'Electricité, of Liège, and the Anciens Ateliers de Constructions van den Kerchove, of Ghent—the former well known as manufacturers of general electrical plant, and the latter of steam engines and steam turbines. A new works is being built at Liège for the production by the most modern methods of the smaller classes of electrical machinery, and the works in Ghent will also shortly be extended.

Toyo Denki Seizo Kabushiki Kaishi.—This company holds the rights for the Japanese Empire to manufacture D.K. traction equipment in their works situated near Tokio. It is in close relations with the English Electric Company's Branch Office in Japan.

English Electric Company of Australia, Limited. — This company represents the alliance and extension of two well-known Australian manufacturing companies—the Standard Waygood Hercules, Limited, of Sydney, and G. Weymouth Proprietary, of Melbourne—both engaged in the manufacture and sale of electrical and allied machinery. The new company, which has a capital, locally subscribed, of £600,000, will develop manufacture in Australia, to the designs of the English Electric Company, and act as Australian representative. New works near Sydney are at present being built and equipped with the most modern plant.

In addition, branch offices have been established in the Argentine, Brazil, Canada, India, Japan, New Zealand,

South Africa and the Straits Settlements, while in China the company is represented by Messrs. Jardine Matheson & Company, Limited. A list of the Home and Foreign Branch Offices of the Company and of its Associates abroad will be found at the end of this number.

In another sphere, the company's scheme of organization and manufacture has been steadily developed. The object of that scheme is to make the best use in each works, not only of the equipment and capacity of that works, but of the knowledge and experience of them all. To do this each works is being gradually devoted to the manufacture of that class of machinery for which it is by reason of its lay-out and past history best adapted. This process of reallocation of manufactures is necessarily a gradual process, because it must be carried out in such a way as not to disturb the execution of existing contracts and to ensure continuity of production. But it has been advanced steadily during the period under review. In the series of articles on the several works, of which we publish the last in this number, we have indicated the principles on which this reallocation is based and the method of their application to each works.

SCHEDULE OF MANUFACTURES OF THE ENGLISH ELECTRIC COMPANY, LIMITED.

Electrical Generating Plant of all capacities.

Steam Turbines and Condensers.

Water Turbines and Impulse Wheels.

Internal Combustion Engines.

Rotary Converters.

Static Transformers.

Switchgear and Controlling Apparatus of all kinds.

Electric Locomotives.

Electrical Equipment and Rolling Stock for Railways and Tramways.

Electric Plant for Rolling Mills, Iron, Steel, Copper Works, etc.

Electric Winding Equipments for Mines.

Standard Industrial Motors.

Incandescent Lamps, Domestic Heating Apparatus and Electrical Accessories.

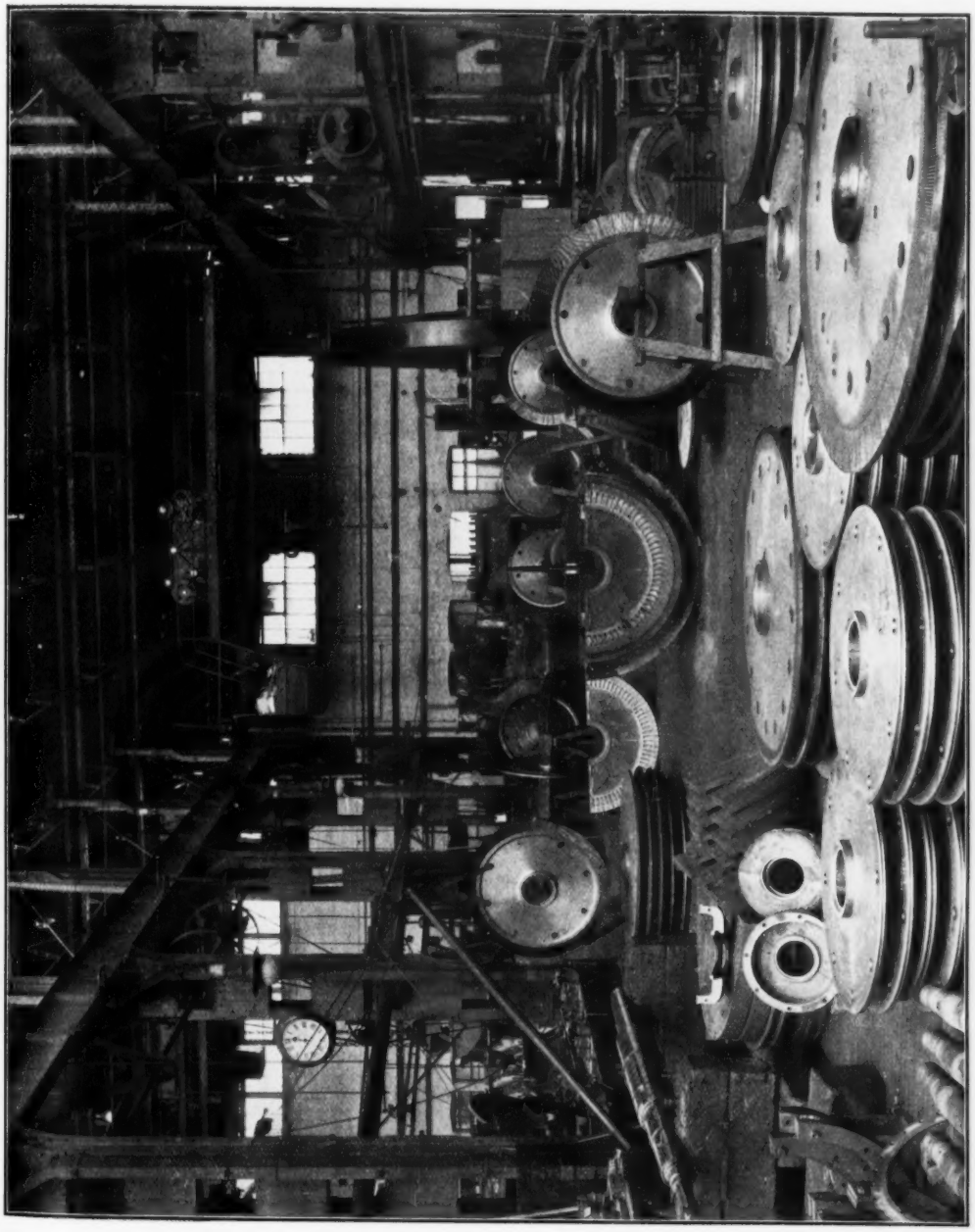
The Willans Works, Rugby.

This is the last of the series of articles describing the Works of the English Electric Company, The earlier articles, which dealt with the Works at Coventry, Preston, Bradford and Stafford, appeared in the first four numbers of the Journal, published in January, April, July and October, 1920.

No. 19 Bay, Heavy Iron Foundry.

The Rugby Works of the English Electric Company stand upon a site forty-one acres in extent adjoining the London and North Western Railway, the property having a frontage on the line of over half a mile. The old company (Messrs. Willans & Robinson, Limited), who transferred their business here from Thames Ditton in 1897, originated about forty years ago in a partnership between the late Mr. P. W. Willans and Mr. Mark Robinson. In 1888 the concern became a private Limited Company, and was later re-constituted as a Public Company in 1893.

The speciality with which the business was



TURBINE BLADING SHOP.

VIEW IN THE MACHINE SHOP.

originally concerned in the partnership days was a small high speed Marine Steam Engine, with the manufacture of which was combined that of steam launches and boilers in a small riverside shop on the Thames at Thames Ditton, near Hampton Court. This was the first high-speed engine which was really successful as regards

culminated, in 1884, in the development of the central valve engine in the form in which it became so well known and met with so great a measure of success during the succeeding twenty years. It remained during that period the chief product of the Company's Works.

Pattern Shop, Pattern and Timber Stores.

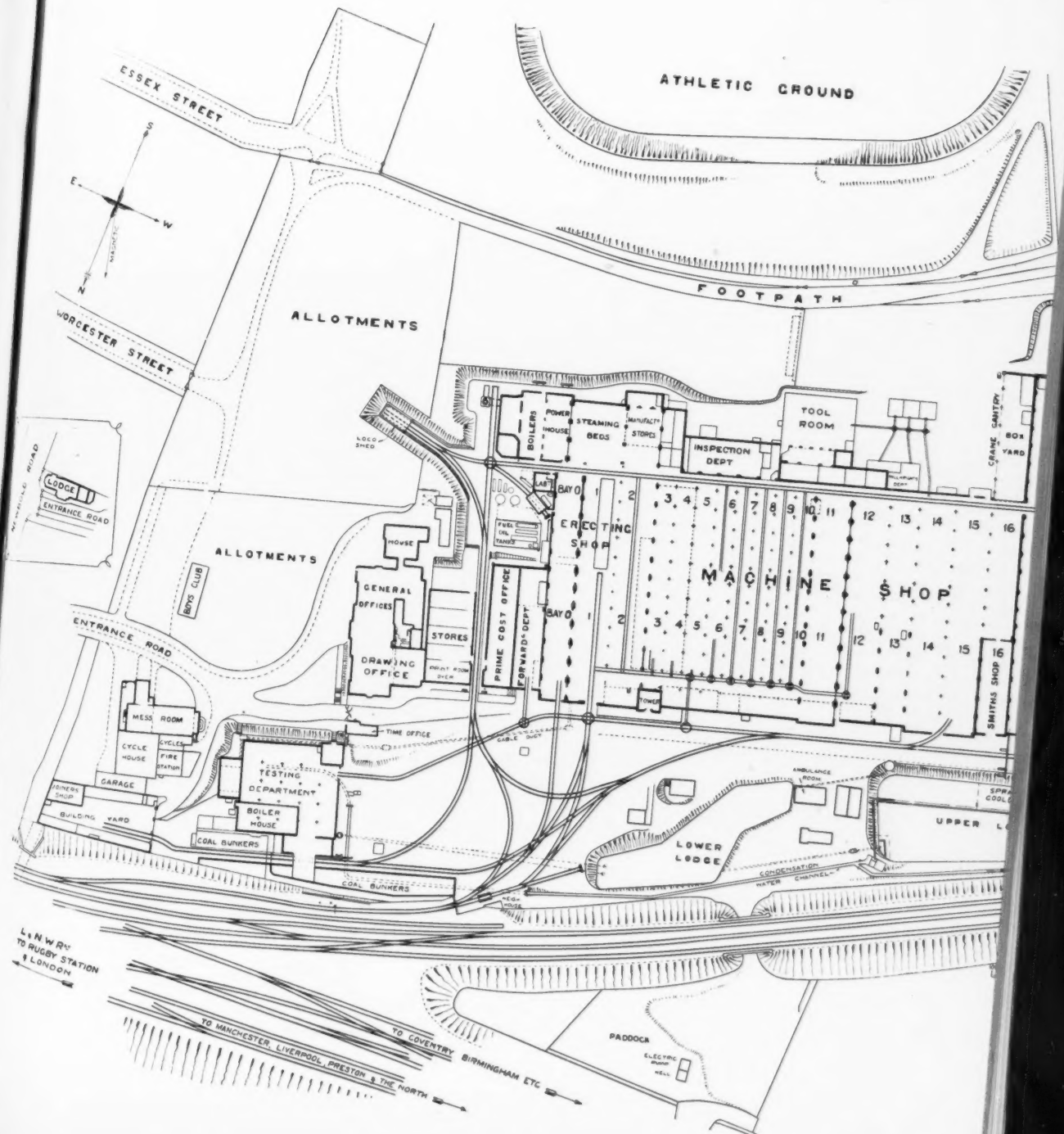
both durability and steam economy, and due to this fact, and to the advent of electric lighting in this country, the suitability of the engine for the direct driving of dynamos was very soon recognised. To render it better fitted for this purpose, however, important additions and improvements were made by Mr. Willans, which

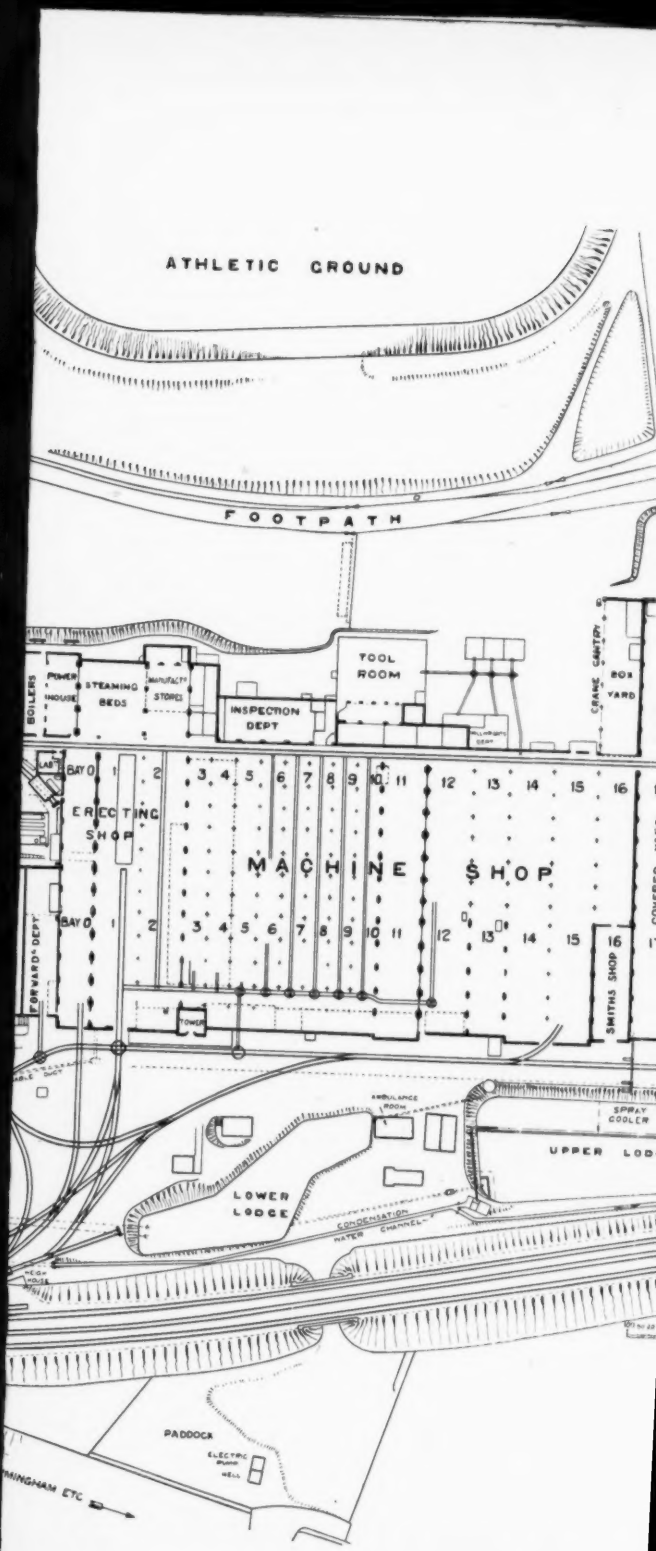
It was the need of room for growth and of better railway facilities that made removal from Thames Ditton imperative. This removal also permitted the laying down and equipment of a completely new factory with every modern improvement; and full advantage was taken of the opportunity so presented.

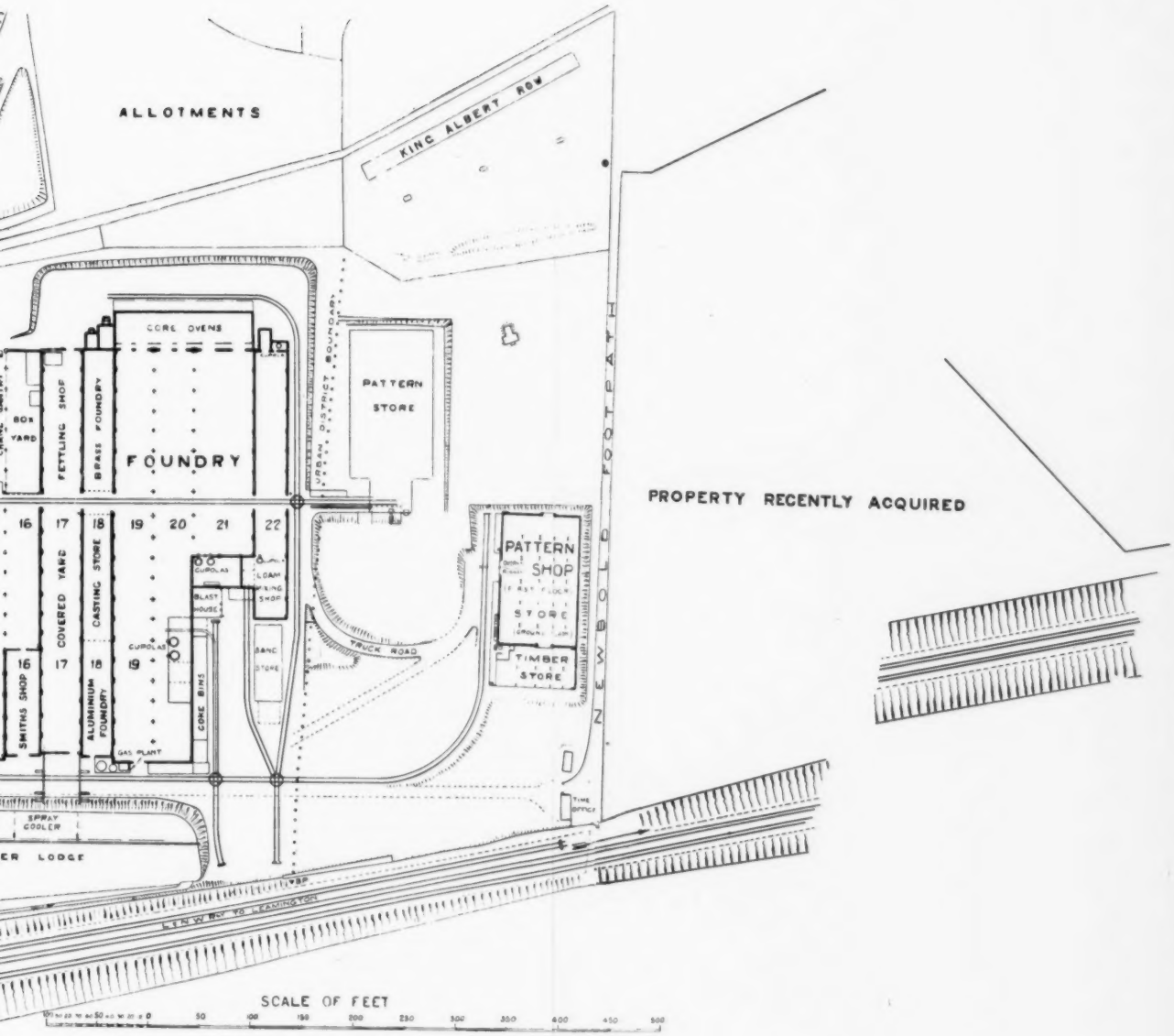
Not long after the removal to Rugby a demand for steam units of larger sizes than those previously manufactured became steadily more urgent. The difficulty of the problems in the design of reciprocating engines to which this demand led gave impetus to the development for land purposes of steam turbines, which had by that time been tried with complete success for marine propulsion. In consequence of this trend of affairs, the Company undertook the manufacture of steam turbines in 1903, and this new development, which met with immediate success, laid the foundations for the extensive manufacture of this type of machine ever since carried on at Rugby.

One of the main features that contributed to the success of the central valve engine, as also to that of the turbines turned out by the Company, was the excellence of the castings; and it was only natural that with the advent of turbine work, attention should have been given to the manufacture of Condensers and Air Pumps, which form so important a part of all turbine installations. Similarly, the rapid development of the automobile industry, particularly in the Midlands, created a demand for small high-grade iron castings, and from 1904 onwards this business was developed extensively at Rugby. At about that time, too, the Diesel Engine was beginning to make headway

PATTERN SHOP.


ESSEX STREET
ATHLETIC GROUND
FOOTPATH
WORCESTER STREET
ALLOTMENTS
ALLOTMENTS
LODGE
ENTRANCE ROAD
BOYS CLUB
ENTRANCE ROAD
MESS ROOM
CYCLE HOUSE
CYCLES
FIRE STATION
GARAGE
JOINERS SHOP
BUILDING YARD
TESTING DEPARTMENT
BOILER HOUSE
COAL BUNKERS
COAL BUNKERS
TIME OFFICE
GENERAL OFFICES
HOUSE
STORES
DRAWING OFFICE
PRINT ROOM
DYER
PRIME COST OFFICE
FORWARD DEPT
LAB
BAY 0
ERECTING SHOP
FUEL OIL TANKS
BOILERS
POWER HOUSE
STEAMING BEDS
MANUFACTD STORES
LOCO SHED
INSPECTION DEPT
TOOL ROOM
MILLWRIGHTS DEPT
CRANE GANTRY
BOX YARD
MACHINE SHOP
SMITHS SHOP
TONGS
CABLE SHOT
AMBULANCE ROOM
LOWER LODGE
CONDENSATION WATER CHANNEL
UPPER L
PADDOCK
ELECTRIC PUMP WELL
L.N.W.R. TO RUGBY STATION & LONDON
TO MANCHESTER, LIVERPOOL, PRESTON & THE NORTH
TO COVENTRY BIRMINGHAM ETC
S
E
W
N
MAGNETIC


ATHLETIC GROUND
FOOTPATH
BOILERS
POWER HOUSE
STEAMING BEDS
MANUFACT STORES
INSPECTION DEPT
TOOL ROOM
CRANE CANTRY
BOX YARD
LAB
BAY 0
ERECTING SHOP
MACHINE SHOP
FORWARD DEPT
TOWER
SMITHS SHOP
AMBULANCE ROOM
SPRAY COOLER
UPPER LODGE
LOWER LODGE
CONDENSATION WATER CHANNEL
PADDOCK
ELECTRIC PUMP WELL
HINGHAM ETC



THE
ENGLISH ELECTRIC COMPANY LIMITED
WILLANS WORKS
RUGBY
GENERAL PLAN

DIESEL ENGINE TEST BED.

on the Continent, and the fact that the Rugby Works had always been associated with work requiring a high degree of accuracy, and manufactured on such a basis as to be interchangeable, rendered the Diesel Engine a very suitable product for works which had also been laid down primarily to deal with a high-grade type of Reciprocating Engine. From that time until the present day the production of Diesel Engines has been carried on as one of the main lines of manufacture concurrently with turbines and condenser plants.

Office Buildings.

The works buildings have been extended and improved from time to time for increases in the volume and changes in the character of the work undertaken. These extensions have been carried out in conformity with the original plans, in which, from the outset, provision was made for systematic development as occasion might require in the future. From the first, also, the questions of railway siding accommodation, loading, storage, and the orderly progression of material from stage to stage have been very carefully kept in view. The result is that the works buildings to-day, which have been nearly trebled in area since first established, and cover about seven acres under roof, are in every respect conveniently disposed for economical handling of the products and present the same compact and symmetrical appearance as in the original project.

As will be seen from the plan, the front of the works buildings faces north, nearly parallel with the railway, between which and the shops is an open space tapering from 200 to 100 feet wide. A line of rails runs outside the full length

of the works, and between these and the railway are two "lodges," or ponds, used for water supply and cooling purposes.

This main block of buildings, comprising the Machine and Erecting Shops, is constructed in bays running north and south, divided in some cases by brick piers and arches, but generally by lattice steel stanchions which carry the traveller girders. At a higher level the stanchions carry cross girders running east and west. These support rolled steel gutters and light principals, the latter carrying the "weaving shop" type of roof, the ridges and gutters of which run east and west; the light is from the north.

At the west end of the main block is the foundry, with a total floor area of 58,700 sq. ft., of which 11,700 sq. ft. are devoted to brass founding. To the west of the foundry, and completely detached, are the Pattern Shop and Pattern Stores, with a total area of 22,000 sq. ft.

All the shops are well lighted and ventilated and are provided with efficient modern machine tool equipment. Included in the tools most recently installed are a heavy internal grinding machine suitable for dealing with large internal combustion engine cylinders, and a heavy crank grinder; both these machines are amongst the largest of their type in use in this country. There is also a well-equipped Chemical and Metallurgical Laboratory, which is situated at the south-east corner of the Works block, close to the Power House. Current is generated in the Power House for Works lighting and power purposes by Diesel Engine driven sets. A battery of Water Tube Steam Boilers also adjoins the Power House for supplying steam for turbine testing.

The Office buildings, in which are accommodated the Technical, Drawing Office and other staffs, are at the eastern end of the Works, and are approached by a private road. Adjoining the open space in front of these buildings are the Testing Department block and a brick-built Mess Room for the use of the employees; also the Works Fire Station.

We have shown in previous articles how the English Electric Company has taken advantage of the combination of several Works under one control to re-distribute the ranges of electrical manufactures in such a way as to make the most efficient use of the facilities available in each Works. The same principles have been followed in regard to the general engineering or mechanical products with which the Rugby Works have been so far exclusively concerned. The dimensions and equipment of the larger shops at the Ordnance Works, Coventry, render them especially suitable for the heavier class of turbine work. The present tendency in the matter of prime-movers is in the direction of larger units for the generation of power in municipal and other supply stations. This has involved the development of turbines and auxiliary plant heavier than the Rugby Works can most conveniently undertake, whereas those Works are particularly well laid out for dealing with High-Speed Turbines of the lower ranges of output. It is intended, therefore, to manufacture there turbines of all sizes up to about 5,000 K.W. capacity, Coventry Works taking over the upper ranges.

The manufacture of Internal Combustion Engines of Diesel and other types is to be concentrated at Rugby, where the shops are, as already indicated, exceptionally well adapted for such work. The large Iron Foundry, with a capacity much in excess of that required to supply the wants of the Rugby Works themselves, will be used to the fullest extent in helping to fill the requirements of the other Works in the way of castings.

The large open plot of land at the south side of the Works is laid out as an Athletic Ground, which covers seven acres, and is devoted entirely to the Willans Works Athletic Club, membership of which is confined to the employees of the Company. There is also a Works Provident Society, which is approved under the Government Scheme for administration of the National Insurance Acts for the benefit of the employees who are members of it.

It is interesting at this time to recall that the principle of "Payment by Results" (Premium Bonus) has been operative in the Works for nearly thirty years, the introduction of the scheme having been made before removal of the business from Thames Ditton. In a Report made to the House of Commons by the Labour Department of the Board of Trade in 1895 on "Gain Sharing" (the Report was afterwards printed for public circulation), the system then in operation in the Willans Shops is specially described.

The Governing of Steam Turbines

By J. P. Chittenden.

With turbines driving electric generators it is of the utmost importance that the speed of rotation shall only vary between fine limits under all conditions and variations of load.

When the electrical load is suddenly reduced the whole of the difference in load exists between the turbine and generator, the turbine producing more power than is called for by the electric generator. This excess of power is absorbed by the rotating elements in the form of kinetic energy, and, as a consequence, the speed of rotation increases rapidly.

When a sudden increase of electrical load occurs the converse action takes place. The extra load required by the generator is supplied at the expense of the kinetic energy of the rotating elements, and, consequently, the speed of rotation rapidly decreases. To avoid an excessive change in speed, it is necessary to employ some form of governing device which rapidly adjusts the power supplied by the turbine to correspond to the demand for electrical power on the generator.

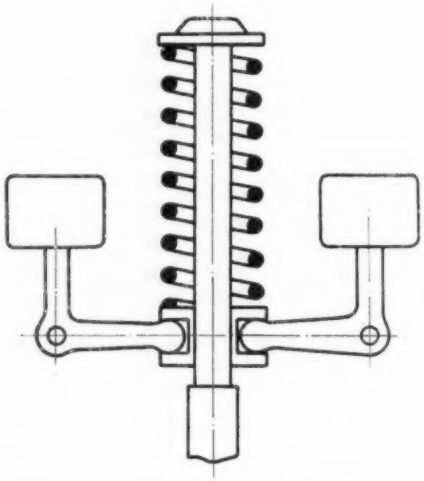


Fig. 1.

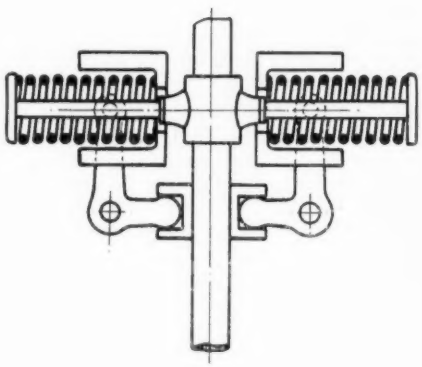


Fig. 2.

The governing device now universally adopted on steam turbines takes the form of a centrifugal governor, which operates the valve or valves controlling the supply of steam to the turbine.

The object of this article is to describe the action of the governor itself, and to show the application of the principles of governing to steam turbines.

Fig. 1 shows diagrammatically the simplest form of a spring-loaded governor, which consists of two loaded balls attached to crank levers, the horizontal arms of which act upon the sleeve against a compression spring. By this arrangement the centrifugal force developed by the rotating balls is transmitted to the sleeve, and so moves the sleeve upwards against the compression of the spring.

The objection to this simple type of governor is that the forces are balanced through the mechanism of the cranked lever, and certain frictional losses unavoidably occur at the pivots. This trouble has been overcome by the introduction of a modified form of governor, Fig. 2, in which the weights act directly upon the compression springs, and the pins are only subjected to the weight of the moving parts.

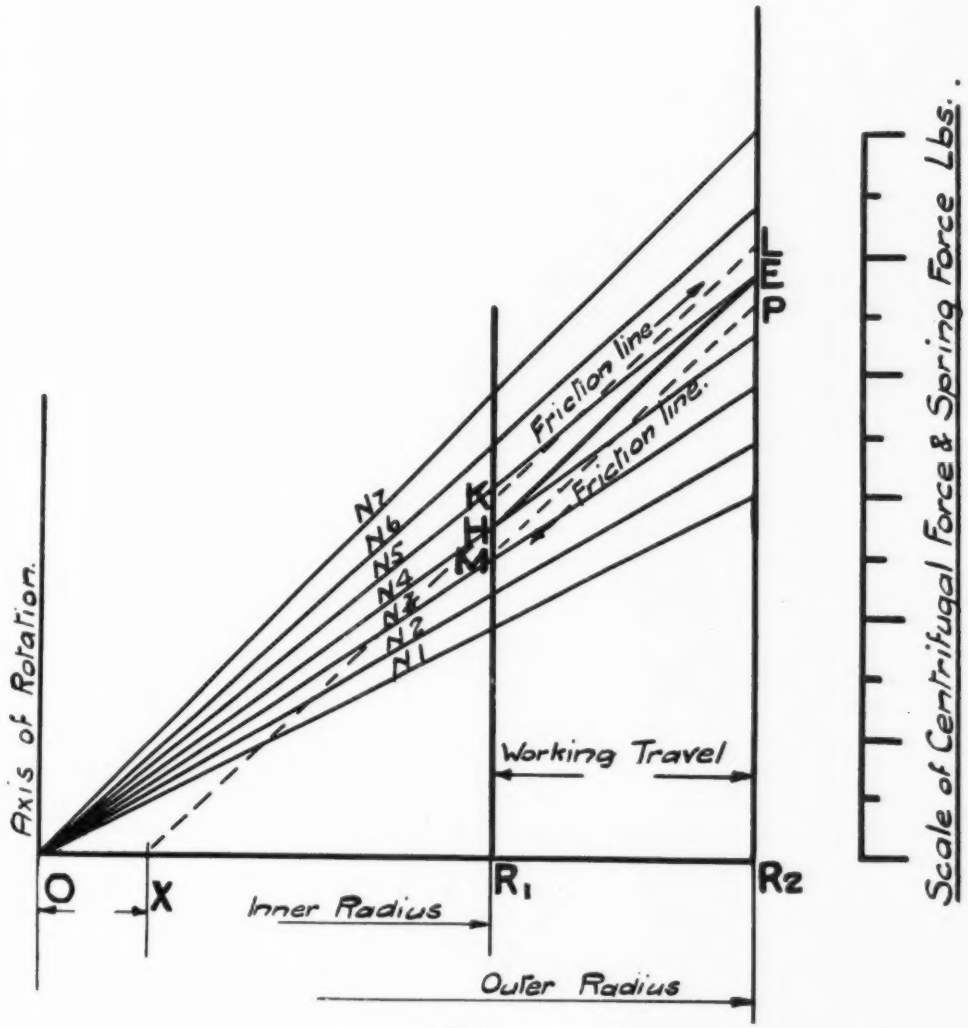


FIG. 3.

In considering the working of the governor the following graphic method (Fig. 3) shows very effectively the forces that come into play.

The vertical line passing through the point "O" represents the axis of rotation, and R_1 and R_2 the inner and outer radius at which the governor balls operate, and since at any fixed speed the centrifugal force is proportional to the radius at which the weight acts, the straight lines radiating from the point "O" represent the centrifugal force of the weights at constant speeds.

Having decided upon the desired total speed variation, which may be taken as N_4 to N_5, the necessary resistance of the spring at the inner and outer position is given by the vertical

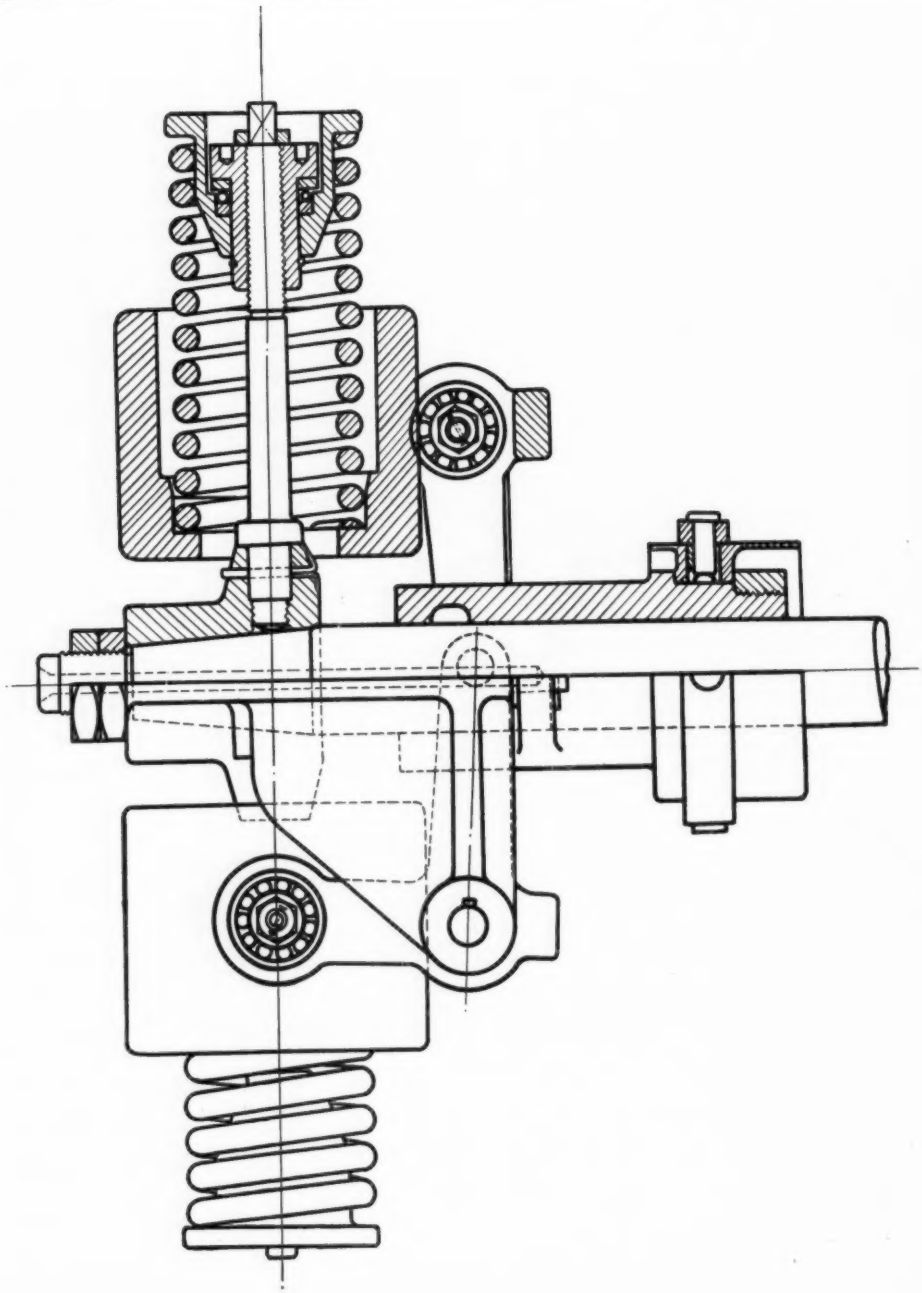


FIG. 4

distance, R_1H and R_2E, the points H and E being the intersection of the vertical lines on R_1 and R_2 with the constant speed lines N_4 and N_5 respectively.

From the diagram it will be seen that the smaller the angle between the spring line and the constant speed line the more sensitive becomes the governor until the limit is reached, when the spring line coincides with a constant speed line and the governor becomes isochronous.

To obtain sensitive governing it is necessary that this angle should be small, and practically an isochronous governor could be used, providing that all the working parts could be made frictionless.

Considering the action of friction in the governor, any frictional resistance that may occur acts against the direction of motion, so that when the weights are travelling outwards the friction may be considered as an additional load added to the spring load, the line "KL" becoming the governing line when the speed is increasing, and, conversely, the line "MP" is the governing line when the speed is decreasing.

It therefore follows that the finer the governing the less must be the frictional resistance, as before a movement of the weights can take place the speed of the governor must change sufficiently to overcome this resistance.

The governor (Fig. 4) adopted for the English Electric Company's steam turbines has been developed with a view to eliminating, as far as possible, frictional resistance. As already mentioned, with this type of governor the weights act directly upon the compression springs, consequently the pins are only subject to the loading of the moving parts, and to reduce the friction further standard ball bearings of the self-aligning type are fitted throughout. In addition to this, the bearings are so arranged that they are free to slide in an axial direction to compensate for any difference in the expansion, also a ball thrust is fitted under the springs to allow for the twisting action which takes place when they are compressed.

The question of the proportioning of the springs is one of the greatest importance, and this has had special attention in the various sizes of governors manufactured. Referring to Fig. 4, it is obvious that, in addition to resisting the centrifugal force generated by the governor weight, the governor spring has also to resist the centrifugal force due to its own weight. The effect of this is that the spring has a varying load in each of its coils, the coil nearest to the governor spindle only being loaded by the centrifugal force of the weight, whereas the outer coil has, in addition to this, the whole of the centrifugal force due to the weight of the spring.

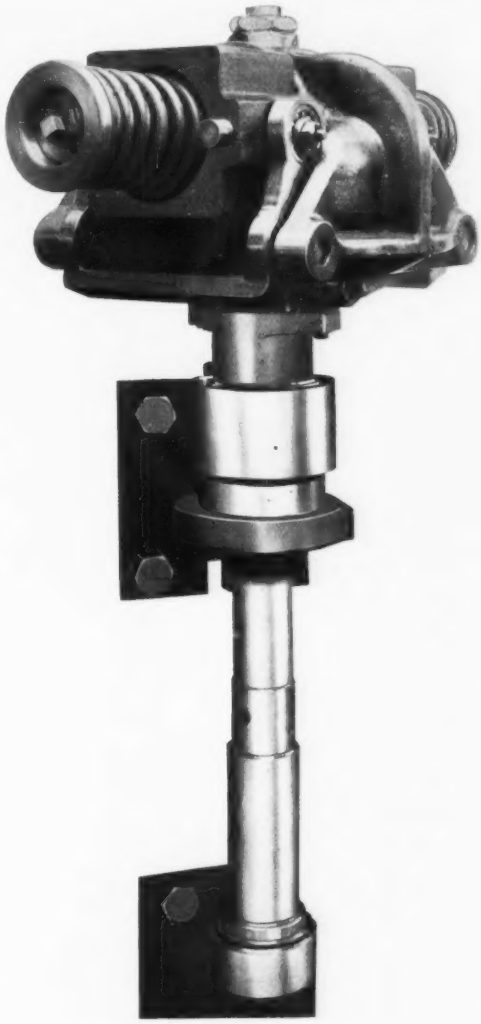


FIG. 5.

To counterbalance this effect the springs in the larger sizes of governor are made of conical form. The smaller diameter coils at the outer end of

the governor have then a greater stiffness, and the deflection of the spring becomes practically uniform over its whole length.

FIG 6.

The governor is carried from the top of the spindle, thus simplifying the attachment between the levers and governor sleeve and permitting the governor to be removed from the spindle for inspection or cleaning without dismantling or in any way interfering with the adjustment of the governor parts; the lubrication of the working parts and sleeve is effected by a hole drilled through the axis of the governor spindle.

Figs. 5 and 6 show photographs of the governor for a 10,000 K.W. turbine.

The method of transmitting the motion of the governor sleeve to the valve or valves controlling the steam supply may be divided into two broad classes: the Direct, and the Relay operated systems.

With the Direct governing system, the power of the governor is directly applied to the throttle valve, so that this power must be proportional to the size and number of valves to be operated; consequently, with a number of valves or valves of large dimensions the power, and likewise the size of governor, becomes considerable, and it is for this reason that for turbines of large output the method of direct control has been almost entirely abandoned in favour of relay operated valves.

With Relay governing, the governor power is not directly applied to the valve, but operates an auxiliary power system which in its turn is used to open and close the steam valve on the turbine.

The usual motive power employed on the auxiliary power system is oil under pressure, although in some cases steam is used.

A simple arrangement of Relay gear is shown in Fig. 7, where the governor is connected by means of a lever over a fixed fulcrum to an oil valve "V," the oil from this valve passing to the underside of the relay piston "P." A constant leak off pipe "L" is employed upon the relay cylinder, and a compression spring on the top of the piston tends to keep the piston down and the steam valve closed. Under working conditions the load of the spring is balanced by the oil pressure under the piston, and this pressure varies according to the relative opening of the valve "V" to the leak off area "L."

An increase of load on the Turbine and consequent decrease of speed causes a fall of the governor sleeve, and an increase in the opening of the valve "V," admitting more oil to the relay cylinder. The increased pressure

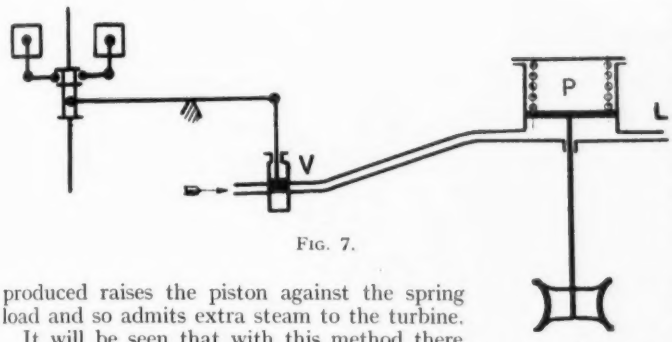


FIG. 7.

produced raises the piston against the spring load and so admits extra steam to the turbine.

It will be seen that with this method there is no mechanical connection between the governor and the relay piston, and, consequently, the relative position of the governor and the piston depends upon the pressure of the oil supply and, further, the pressure under the piston is entirely dependent upon the relative openings of the valve and leak off pipe " L."

An objection to this method is that it necessitates very careful adjustment of the parts to give satisfactory governing.

A more satisfactory arrangement is arrived at by mechanically connecting the governor sleeve and relay piston; this arrangement is indicated in Fig. 8. The floating lever " F " connects the governor sleeve " E " to the relay piston rod " G," and the oil distribution valve " B " is also connected to the lever. The action of this gear is as follows :—

If the load on the Turbine increases, the governor sleeve " E " falls slightly, the floating lever " F " moving with the sleeve. This movement has the effect of lowering the oil distribution valve " B," thus admitting pressure oil to the underside of the relay piston " C " and at the same time permitting oil to escape from the top side. The relay piston then rises, due to the difference of pressure, carrying with it the throttle valve, and thus allowing a greater quantity of steam to enter the turbine.

The piston rod, in moving upwards, carries with it the lever " F," which now has its fulcrum at the governor sleeve " E," and thus the oil distribution valve is brought back to its normal position and equilibrium is re-established.

It will thus be seen that with this arrangement the relay piston and the governor sleeve have definite relative positions, which are quite independent of such considerations as oil pressure and dimensions of oil passages. The oil pressure necessary is thus only sufficient to overcome the friction of the parts and any steam thrust which may come on to the valves to be operated.

In the case illustrated in Fig. 8, the piston may either work with a spring on one side and oil under pressure on the other, or the oil may be introduced on both sides as shown, where the motion of the governor varies the quantity of oil on each side of the piston.

Both the Direct method and the Relay system of governing can be applied to the steam turbine in two ways. The first, and most simple, is that which causes the opening or closing of the main throttle valve. In this way the common supply of all the nozzles of the turbine is varied directly as the governor speed varies.

The second method of governing turbines is known as Nozzle Valve Control. In point of fact this is very seldom used in direct governing, because the whole object of using the direct governor is to retain the simplicity of the system and to keep down the complications and initial costs of the plant. The application of the method of Nozzle Valve Control to the direct acting governor would necessitate its operating a number of valves, and this would mean the installation of a particularly large and powerful governor, which would be extremely costly.

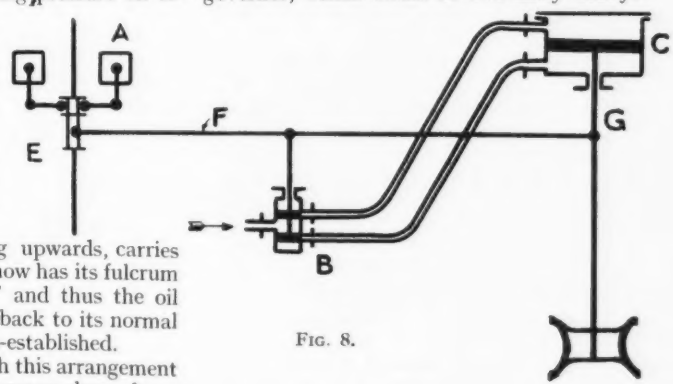


FIG. 8.

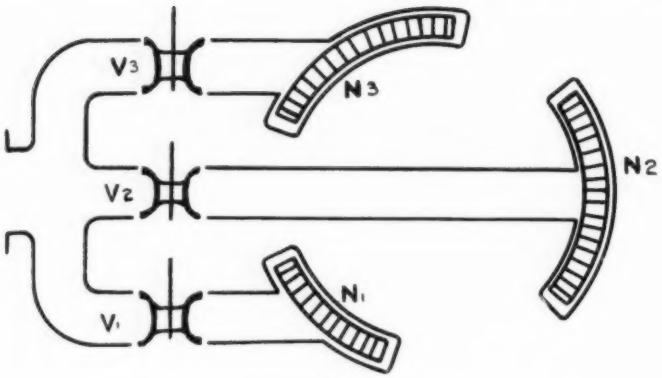


FIG. 9.

With Nozzle Valve Control, the relay system of governing is almost invariably employed, and with throttle governing this is also true for turbines with anything but the smallest of outputs.

Roughly speaking, the nozzle valve method of governing depends upon the principle of controlling the steam supply to a number of banks of nozzles in turn. Suppose, for instance, there are three banks of nozzles supplying steam to the turbine. These (N_1, N_2, and N_3) and their respective valves (V_1, V_2, and V_3) are shown diagrammatically in Fig. 9.

The mechanism by which these valves are worked is known as a lost motion device, and one of the simplest forms of this is shown diagrammatically in Fig.10. The vertical spindle shown is, in the first instance, directly coupled to the valve V_1, but carries, in addition, two stops, T_2 and T_3, which operate the valves V_2 and V_3 respectively.

Starting from no load on the turbine, the spindle first opens the valve V_1 to its maximum capacity. When this has been accomplished, the stop T_2 comes into contact with the valve V_2, and any further movement of the spindle is then utilised in opening the valve V_2 until this, in turn, has reached its maximum capacity. After this the stop T_3 begins to operate the valve V_3, so that a continuous movement of the relay piston will first operate V_1 to its most effective position, then V_2 and finally V_3.

On Impulse Turbines fitted throughout with simple velocity stages it is common practice to employ throttle valve control, but in cases where the first stage consists of a two-row or velocity compounded wheel, some form of nozzle valve control is usually employed, except for machines of very small output.

In the arrangement of the valves for nozzle control two methods may be adopted, which, for purposes of this article, we can call the "Parallel" and "Series" methods of connection respectively. The Parallel method is that shown diagrammatically in Fig. 9. The steam is split up into three paths, V_1, V_2, and V_3. If the turbine is to be shut down completely, all three of these valves must be closed. This does not entirely prevent leakage.

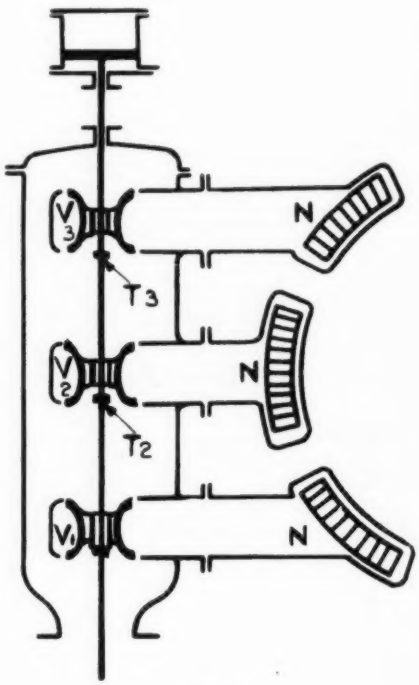


FIG. 10.

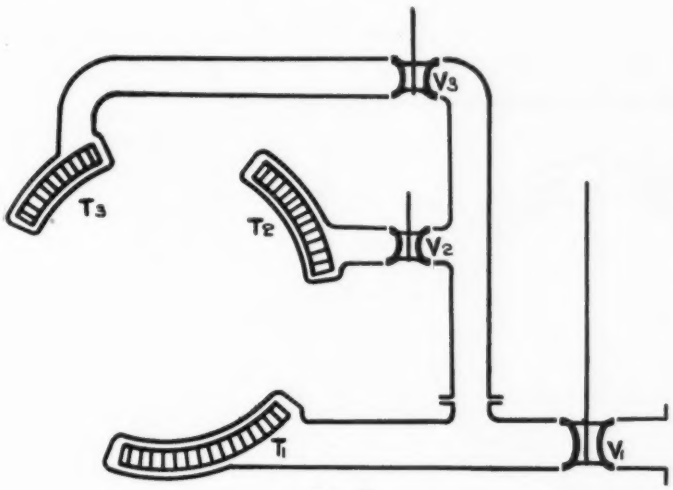


FIG. 11.

For this reason, another method of connecting up the valves has been devised. This we have called the " Series " method, and it is illustrated in Fig. 11. It modifies the arrangement shown in Fig. 9 by making the valve V_1, controlling the first bank of nozzles, a master valve, through which the whole of the steam supply passes. Thus, in order to shut down the turbine completely, all that is necessary is to close the valve V_1, and thus reduce to a minimum the leakage which of necessity takes place when the turbine is not in use.

Until now the steam has been considered as led direct to the nozzles by means of a series of independent pipes. A very good method of introducing the steam to the nozzles is shown diagrammatically in Fig. 12, where each bank of nozzles occupies a segment of a circular belt, into which the steam is admitted by means of valves V_1, V_2, and V_3, corresponding to V_1, V_2, and V_3 in Fig. 11.

Fig. 12 also shows a very effective form of lost motion device which results in V_1 being opened first, then V_2, and finally V_3. The manner in which this is effected will be given later.

All the methods described up to now have been dealt with only as concerning the regulating of the steam supply to the turbine from no load to full load values. When the question of overload is considered, the application of these principles becomes somewhat modified.

Here again two methods can be employed. In the case of turbines with compounded velocity wheels a supplementary bank of nozzles is provided on the turbine which does not come into use unless the turbine is called upon to take an overload.

Upon the advent of overload, this bank of nozzles is called into play, and thus supplies additional steam to the turbine, which takes the overload, the main governor in effect continuing its function as if normal load were being applied to the turbine continuously throughout this operation.

This is referred to as the nozzle valve method of controlling overload. The second method is generally applied to turbines with simple velocity wheels only. It is shown diagrammatically in Fig. 13, and depends upon the fact that the pressures applied to the turbine drop as the steam passes through the various stages.

The simple velocity turbine is so arranged that in order to produce the respective pressures required at the various stages A, B, C, D and E (Fig. 13), steam is made to enter upon the stage " A " at as nearly as possible full boiler pressure under full load conditions.

Hence, as it is impossible to raise the pressure at which the steam enters into the initial stage " A," the method has been adopted for this type of turbine of taking steam at full boiler pressure by means of a bye-pass directly to one of the later stages of the turbine. Thus, upon the advent of overload, full pressure steam is admitted to, say, stage " C " of the turbine, and this raises the pressure of the whole of the later stages C, D and E, of the turbine. This method is known as controlling overload by means of a bye-pass valve. Here again the governor in effect continues to work under normal load conditions, the whole of the overload being carried by the steam admitted through the bye-pass.

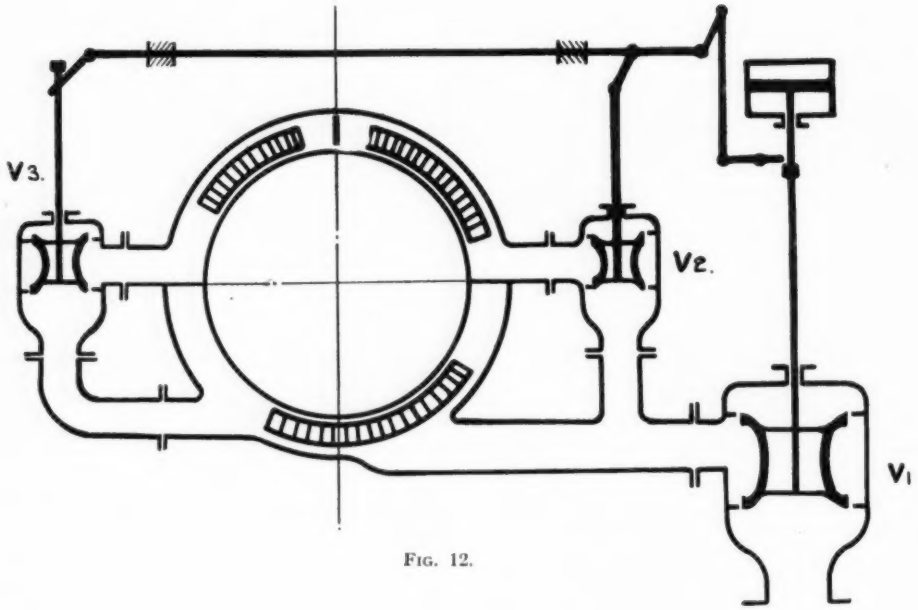


FIG. 12.

Both of these types of valves can be controlled either by hand or by the governor. In the case of direct governing where throttle control, as applied to small output turbines, is the only system to be considered, the overload steam can be admitted in two ways, either by means of a hand-operated bye-pass valve, as is done with turbines employing simple velocity wheels, or by means of a hand-operated nozzle valve, which is the method generally adopted for small turbines with compounded velocity wheels.

When governing by the relay method of throttle control, the overload steam can be admitted in three ways. With small turbines employing compounded velocity wheels the overload steam is admitted, as in the case of the direct governing throttle control, by a hand-operated nozzle valve, but with large turbines with simple velocity wheels bye-pass valves are usually employed, and these in turn can be either hand-operated or governor-controlled.

With the relay method of governing by nozzle control, which is applied, as previously stated, only to large turbines with compounded velocity wheels, the overload steam is almost invariably admitted by means of a governor-controlled nozzle valve.

Fig. 14 gives a diagrammatic representation of the relation existing between the various methods adopted for the governing of steam turbines, and shows at a glance what methods are generally adopted under given conditions.

The nozzle control gear adopted by the English Electric Company is shown in Fig. 15. The principle of this gear is the same as described in Figs. 11, 12, and 13, namely, the "series" method of control. The three valves employed are mechanically operated by the main oil relay piston, the first or main valve through which all the steam passes controls by throttling up to about 60 per cent. of the normal load. When this valve is lifted to the extent necessary to pass the required quantity of steam, a stop on the spindle of the relay piston engages with the bell crank lever which operates the full load nozzle control valve.

When this full load valve is fully opened, a further travel of the relay piston opens the nozzle control valve for overload, the connection to this valve being obtained by means of a weigh shaft. It will thus be seen that the single relay piston, which is actuated throughout its complete range of travel by the main governor, has full control of the steam supply from no load to maximum overload. Further, as already mentioned, with this system the whole of the steam supplied to the turbine passes through the main valve and, consequently, any leakage which might occur through the auxiliary nozzle valves on light loads is greatly reduced, as compared with the " parallel " system of nozzle control described in Figs. 9 and 10, where all the valves are subject to the full steam pressure.

This arrangement of valve gear has the further advantage that any valve can be removed for inspection without disturbing the remaining parts or the general setting of the governor gear, and also with this arrangement the top half of the turbine casing can be removed for inspection without necessitating the breaking of any steam connections or dismantling any of the valve gear.

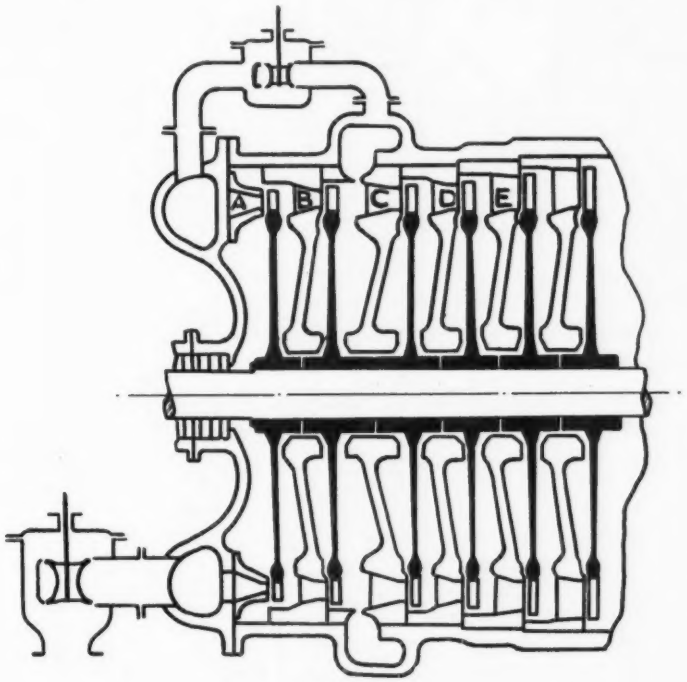


FIG. 13.

(*For Figs.* 14 *&* 15 *see pages* 188 *&* 189).

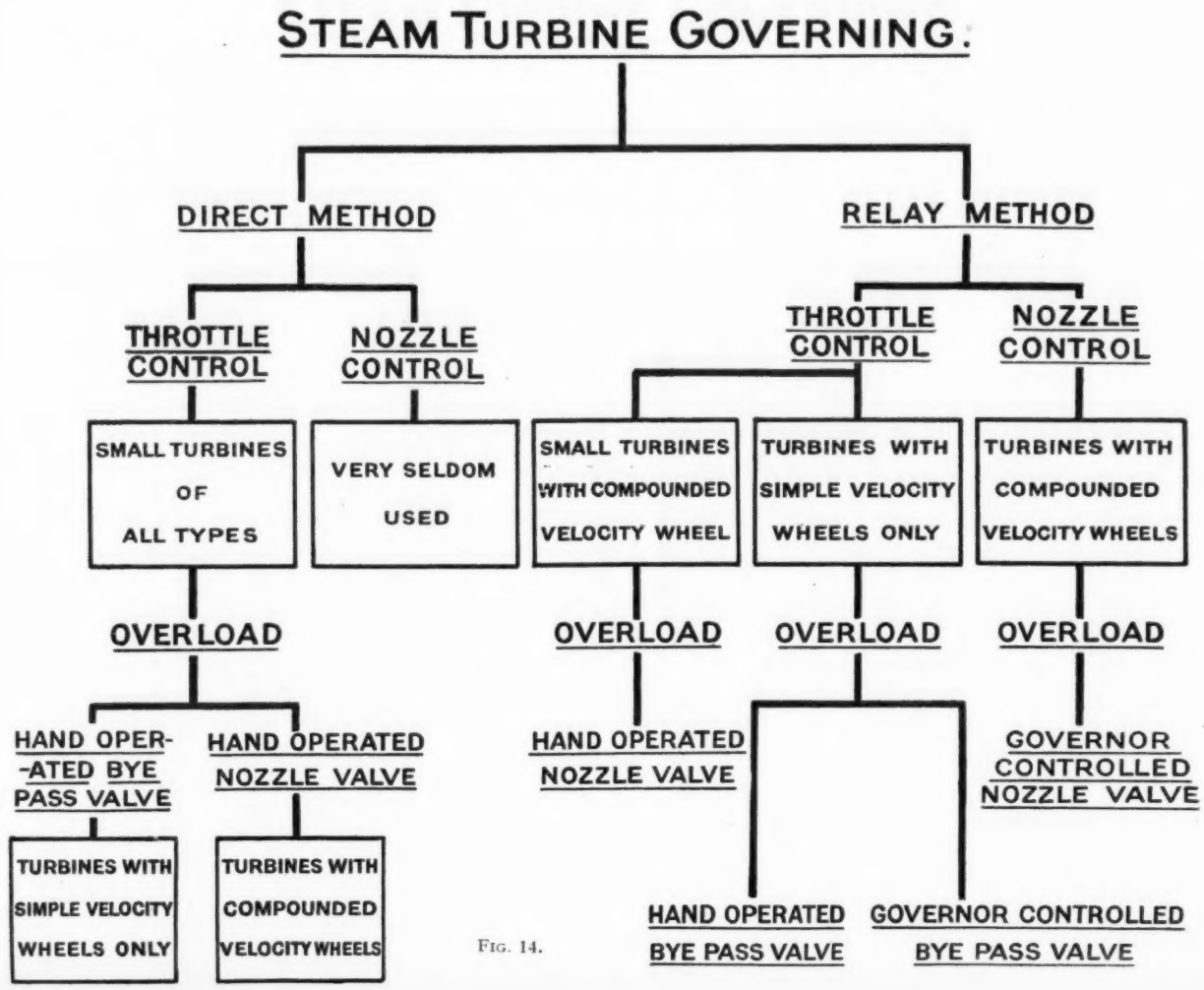

STEAM TURBINE GOVERNING.
DIRECT METHOD
RELAY METHOD
THROTTLE CONTROL
NOZZLE CONTROL
THROTTLE CONTROL
NOZZLE CONTROL
SMALL TURBINES OF ALL TYPES
VERY SELDOM USED
SMALL TURBINES WITH COMPOUNDED VELOCITY WHEEL
TURBINES WITH SIMPLE VELOCITY WHEELS ONLY
TURBINES WITH COMPOUNDED VELOCITY WHEELS
OVERLOAD
OVERLOAD
OVERLOAD
OVERLOAD
HAND OPER--ATED BYE PASS VALVE
HAND OPERATED NOZZLE VALVE
HAND OPERATED NOZZLE VALVE
GOVERNOR CONTROLLED NOZZLE VALVE
TURBINES WITH SIMPLE VELOCITY WHEELS ONLY
TURBINES WITH COMPOUNDED VELOCITY WHEELS
HAND OPERATED BYE PASS VALVE
GOVERNOR CONTROLLED BYE PASS VALVE

FIG. 14.

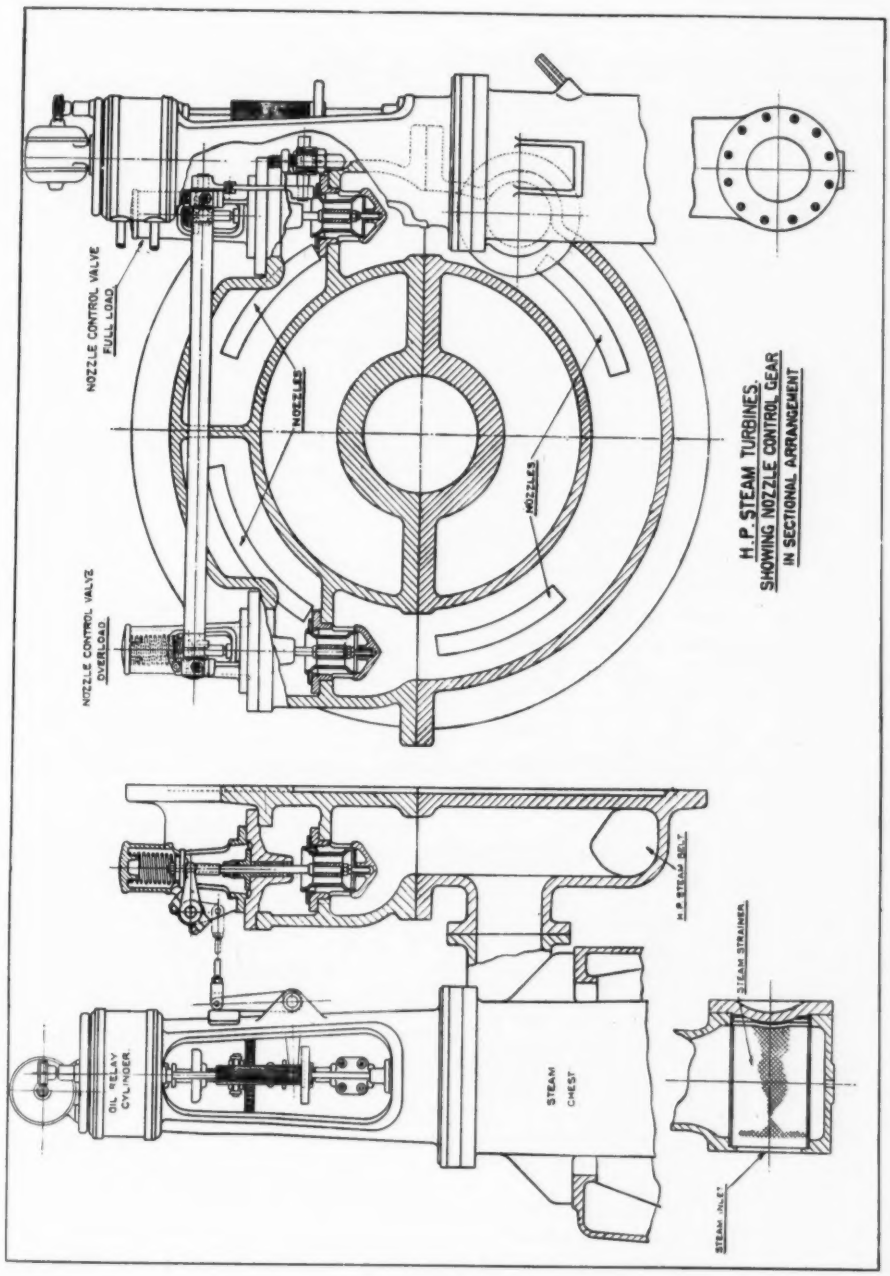

H.P. STEAM TURBINES
SHOWING NOZZLE CONTROL GEAR
IN SECTIONAL ARRANGEMENT
NOZZLE CONTROL VALVE
FULL LOAD
NOZZLE CONTROL VALVE
OVERLOAD
NOZZLES
NOZZLES
H.P. STEAM INLET
STEAM STRAINER
STEAM INLET
STEAM CHEST
OIL RELAY CYLINDER

FIG. 15.

Electricity in the Tinplate Industry

By L. Rothera, B.Sc., A.M.I.C.E., M.I. & S.Inst.

A field in which electricity has not yet played a very prominent part is the tinplate industry, centred in South Wales. A certain number of important works have adopted the electric drive, which has given satisfactory operation for many years, but there is a reluctance on the part of other works to adopt a similar drive, although it is to be anticipated that the results of its adoption would prove to be as satisfactory in this as in other branches of steel works practice.

A consideration of the problems involved serves to show wherein the electric drive is preferable to any other form of prime mover.

The rolling mills in a tinplate works consist of the Hot Mills and the Cold Rolls, in connection with which a considerable number of auxiliary machines, such as shears, doublers, pickling machines, barring gears, tinhouse plant, etc., are necessary.

Each Hot Mill in English practice consists of two pairs of rolls with an average diameter of about 22 ins. and a length of 32 ins., the first pair being used for breaking down the material ; and the second pair for finishing it. This procedure is adopted in order that the plates shall be finished by a pair of rolls whose surface is undamaged by the heavy work entailed in the breaking-down rolls.

The number of Hot Mills driven by one power unit depends on the size of the works. In a small plant two or even one Hot Mill will be driven, whilst in a larger plant four or six Hot Mills may form a unit, the mills being arranged symmetrically on each side of the drive, i.e. in a four-mill drive two mills would be on each side, and in a six-mill drive three.

The Cold Rolls deal with the plates leaving the Hot Mills after they have undergone a process of pickling and annealing. The function of the Cold Rolls, so called from the fact that they deal with the plates cold, is to produce a highly burnished surface necessary for receiving the coating of tin.

The number of rolls is dependent on the number of Hot Mills, and for a twelve Hot Mill plant 22 or 24 Cold Rolls would be required. For convenience, the Cold Rolls are arranged in a series of trains—five or six to a train—and driven through lines of gearing by one or two motors.

Process of Tinplate Manufacture.

The raw material is received in the form of a tin bar, which consists of lengths of steel strip varying from 7 in. to 10 in. wide by $\frac{3}{8}$ in. to $\frac{7}{8}$ in. thick, the sizes varying in accordance with the class of tinplate to be rolled.

These bars are cut up into short lengths, 16 ins. to 20 ins. long, and a certain number forming a heat are placed in one of two heating furnaces adjacent to each Hot Mill. When the heat attains the desired temperature, two pieces (known as thick iron) are withdrawn simultaneously and thrown along the floor to the roller standing on the near side of the mills. He picks up the two pieces and passes them through the rolls, one immediately after the other, and whilst they are being passed back over the top of the upper roll the rolls are screwed down ready for a second pass. The rolling continues until the plates are too cold for further satisfactory working, when they are returned to the second furnace for re-heating.

The rolling of the thick iron continues until the heat is entirely finished and the plates formed are all in the second furnace. After re-heating, the singles, as they are called, are rolled out to about twice the length and doubled over, forming " doubles," which go back to the furnace for a second re-heat. The doubles are then rolled and bent over to form " fours," again returning to the furnace for a third re-heat. Similarly, the fours are rolled and doubled to form " eights," which, after a fourth re-heat, are rolled out to the final thickness.

The pack of plates is then sheared to size and separated, and the individual plates undergo a pickling process before being put into the annealing furnaces. After annealing they pass forward to the Cold Rolls and go through the rolls a number of times until the final surface is produced. They are then annealed again and

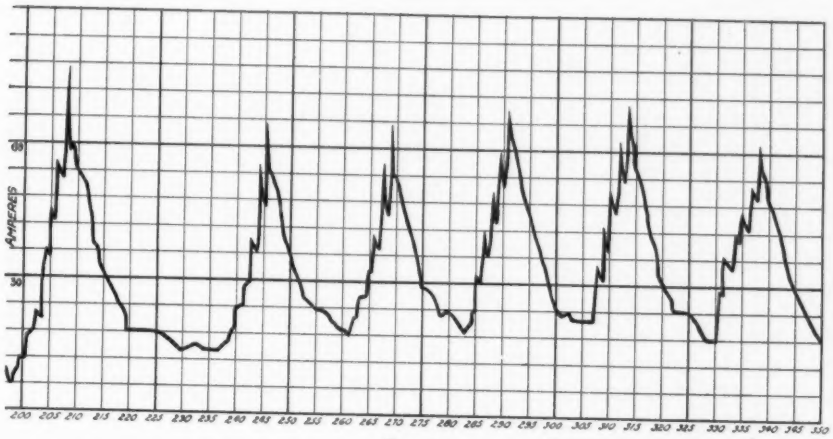

AMPERES
200 205 210 215 220 225 230 235 240 245 250 255 260 265 270 275 280 285 290 295 300 305 310 315 320 325 330 335 340 345 350
TIME IN SECONDS

FIG. 1.

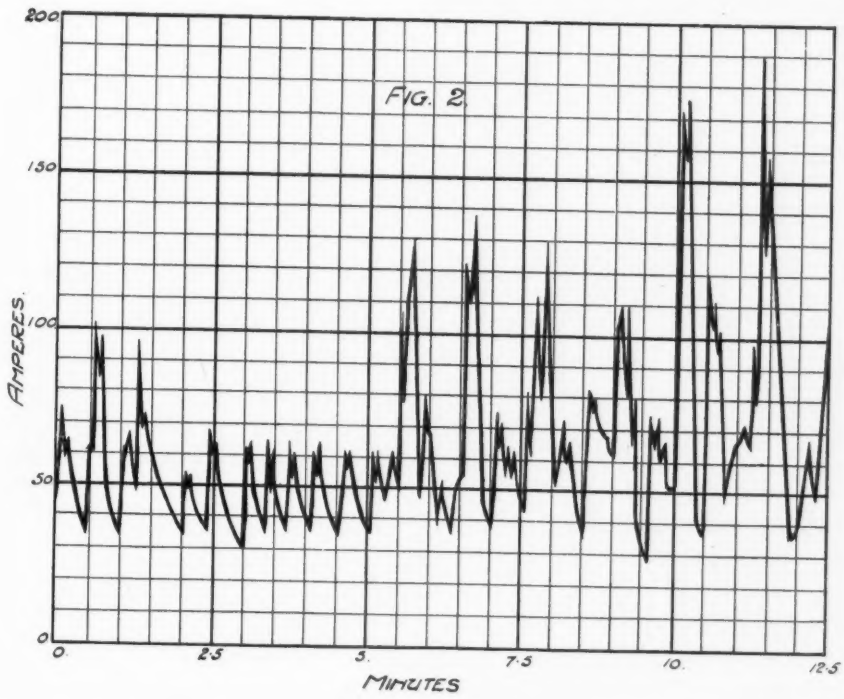


FIG. 2.
200
150
100
50
0
AMPERES.
0.
2·5
5.
7·5
10.
12·5
MINUTES

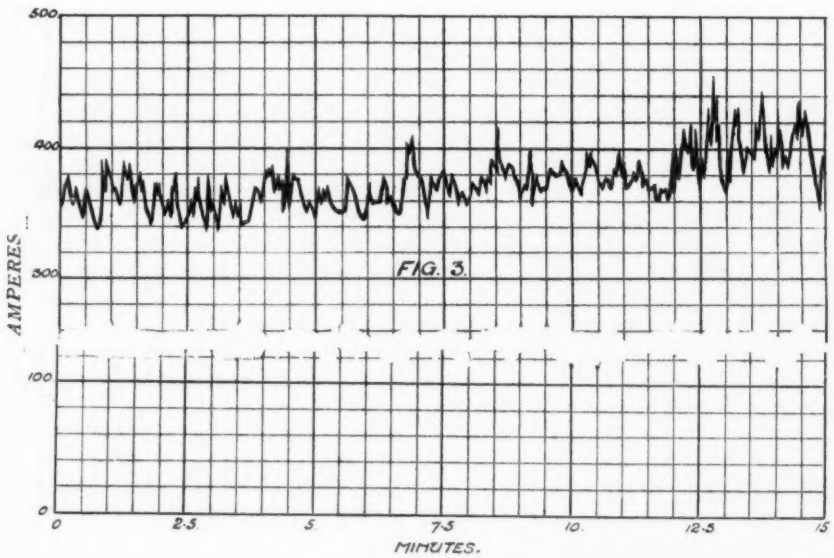

500
400
300
100
0
AMPERES.
0
2·5
5.
7·5
10.
12·5
15
MINUTES.

FIG. 3.

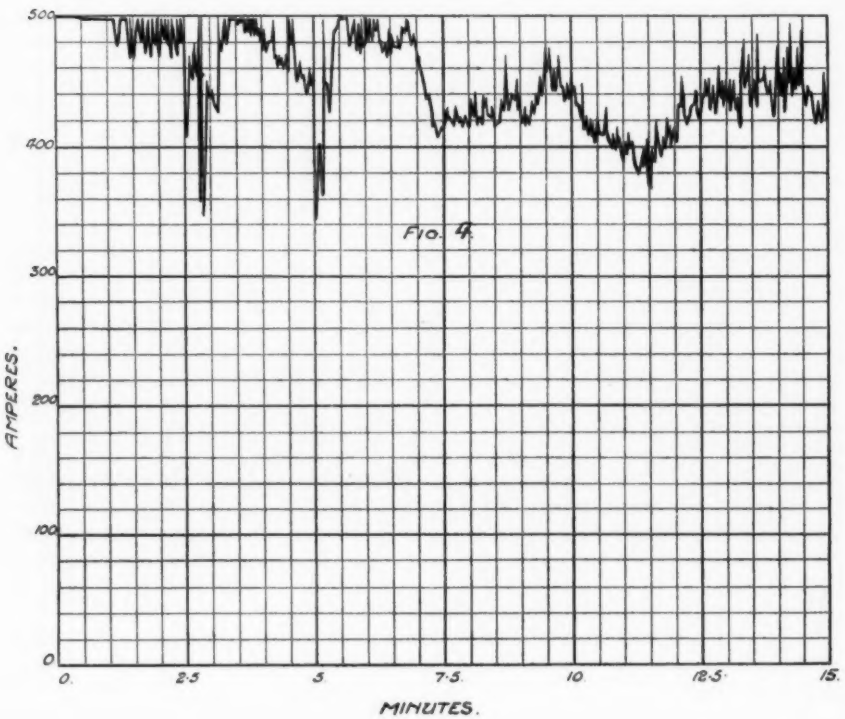

500
400
300
200
100
0
AMPERES.
0.
2·5
5.
7·5.
10
12·5
15.
MINUTES.

FIG. 4.

FIG. 5. — VIEW SHOWING LAY-OUT OF HOT-MILL PLANT.

pickled and passed forward to the tinning room, where they are coated by dipping into baths of molten tin, special methods being adopted to ensure a continuous and uniform coating—a question of the first importance.

Power Demand for Rolling.

The load on a Hot Mill fluctuates very widely, in spite of the levelling effect of a heavy flywheel interposed between the motor and the drive, and Fig. 1 shows the varying current demand on the mill motor when rolling thick iron in one mill.

Fig. 2 is the curve of power taken from a four-mill plant driven by a 600-H.P. motor under normal working conditions, a flywheel 104 tons in weight, 30 ft. in diameter, being interposed between the drive and the mills. This latter curve does not show the worst conditions which arise in practice, as the portion of the curve shown refers to a period when "thick iron" was being rolled in one pair of rolls, "doubles" in two pairs of rolls, and "eights" in one pair of rolls. A considerably heavier load occurs at the beginning of a shift when all the mills are rolling "thick iron" simultaneously, when peaks of 1,000 H.P. and over are likely to occur.

In contradistinction to the Hot Mills, the load on Cold Mills is practically constant. This follows from the great friction load produced by the heavy pressure placed on the necks of the rolls by the screw-down gear and from the large number of rolls engaged at the same time.

A suitable size of motor for driving 24 Cold Rolls would be 600 H.P.

The auxiliary drives will vary in power from 20 to 50 H.P., and most of them are intermittently loaded. The combined effect of these machines would produce a fairly constant demand from the station.

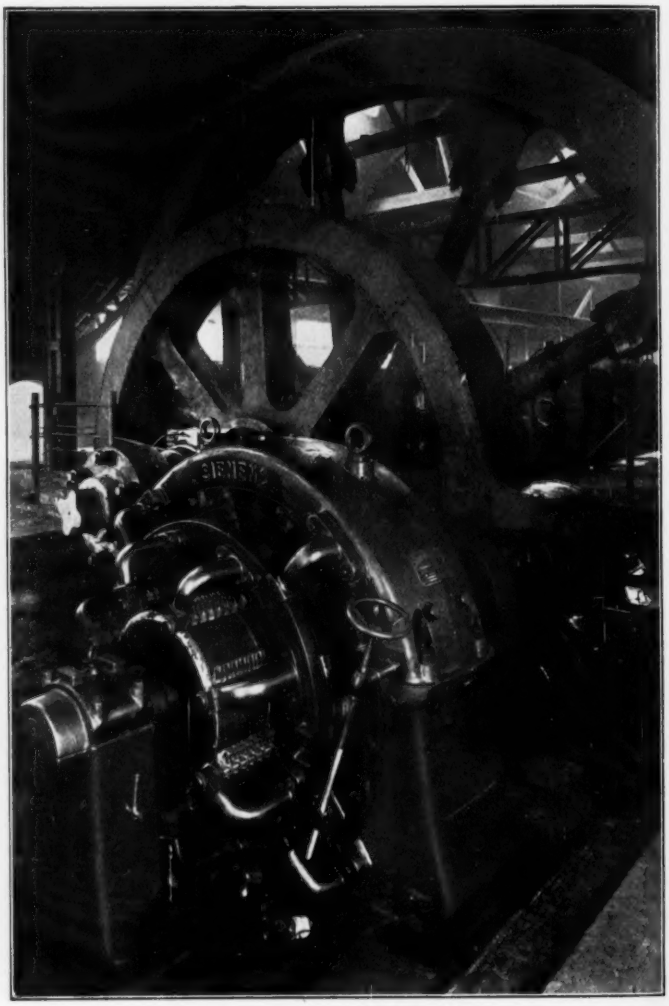


Fig. 6. — 500-H.P. Hot-Mill Motor.

Central Station Demand.

The load conditions of the Central Station for a plant consisting of 12 Hot Mills, 24 pairs of Cold Rolls and Auxiliaries, is shown by curve, Fig. 3, from which it will be seen that throughout

FIG. 7. — VIEW OF COLD-ROLL PLANT.

normal running conditions a comparatively steady demand is experienced, illustrating in a marked degree the levelling out effect of a number of motors working on widely fluctuating loads. The conditions, however, attendant at the beginning of a shift, when all the mills are working simultaneously on thick iron, must be borne in mind, and Fig. 4 shows the effect of this condition, from which it will be seen that the average load rises from, roughly, 350 amperes to 500 amperes during this period.

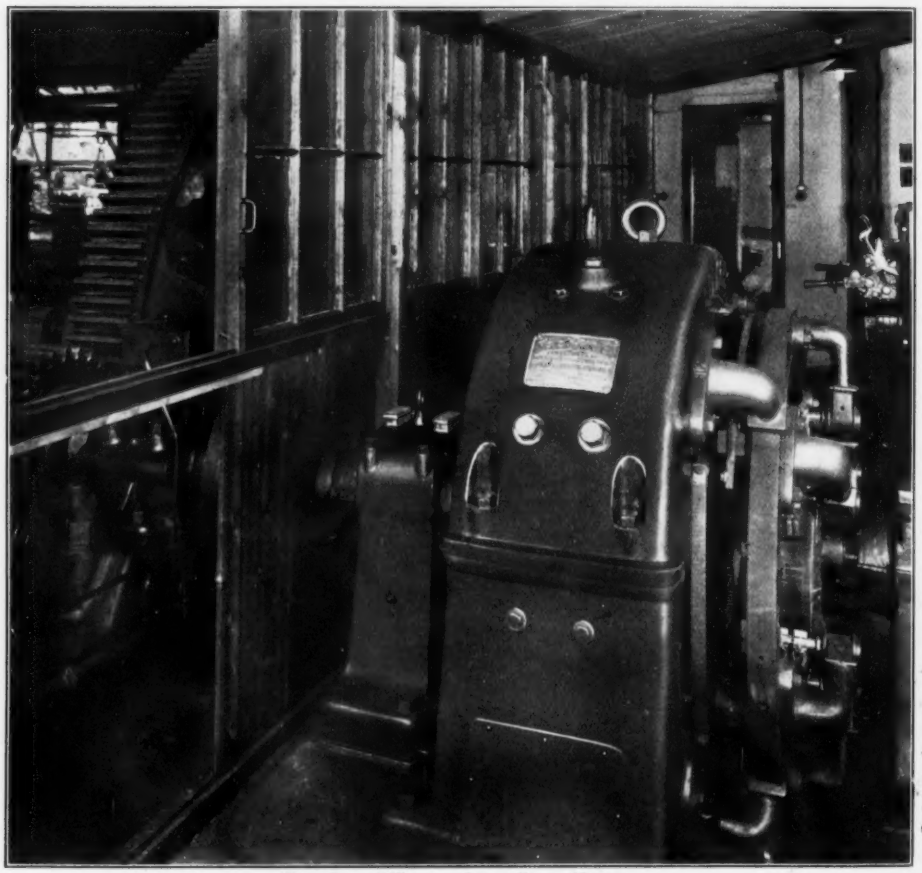


FIG. 8. — 225-H.P. COLD-ROLL MOTOR.

ADVANTAGES OF ELECTRIC ROLLING.

It is an accepted fact that the electric motor shows to particular advantage over a steam engine from the efficiency point of view, where a fluctuating demand for power has to be met and Figs. 1 and 2 show clearly how such conditions occur in tinplate works. As the major proportion of the load is required for the Hot Mills, the conditions are most favourable to the installation of the electric drive.

The same remark applies to the auxiliaries, which are now almost invariably electrically driven, experience having shown that a very great saving is to be made by adopting this method. Since an electric motor is at least as efficient on steady load as a steam engine, i.e. for the cold roll drive, there seems no reason to doubt that the future will show rapid conversion of existing steam-driven mills to electric drive.

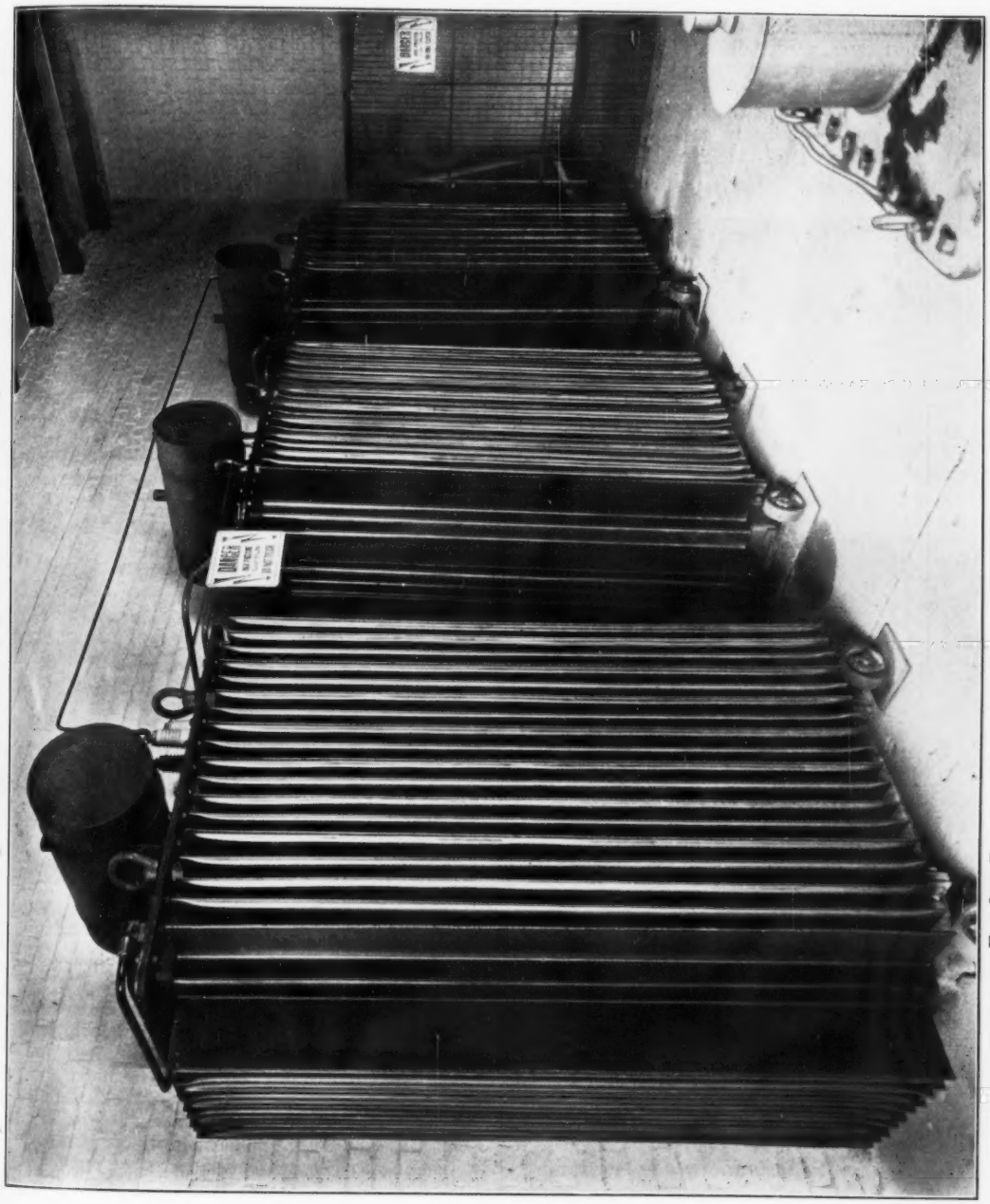


FIG. 9 — BANK OF THREE SINGLE PHASE TRANSFORMERS FOR 500 K.W. ROTARY.

Types of Drive.

Various methods have been used hitherto for driving the mills, the earlier equipments showing, in most cases, a rope drive. Later equipments have shown a tendency to adopt a gear drive in preference, owing to the somewhat heavy continuous losses which occur in the ropes and to the space taken up by this form of drive.

Fig. 5 shows a typical lay-out of a four-Hot Mill plant. The four sets of rolls on the near side of the drive are clearly seen, whilst between the two sets of mills and adjacent to the flywheel are the two doublers and shears.

The flywheel in the centre of the four pairs of mills is 110 tons in weight, 34 ft. in diameter; and Fig. 6 shows a 500-H P. direct-current motor driving down to the mill through gearing.

Fig. 7 gives a view of the Cold Rolls, which, in this instance, are arranged in two lines of stands, each containing three sets of rolls; and Fig. 8 shows the 225-H.P. direct-current motor geared to the mills, the pinion on the motor shaft driving on to the two slow speed spur wheels, one on each side.

The direct-current drive was adopted in order to comply with the power company's requirements of unity power factor, and from the preference felt for direct-current for the auxiliary drives

The incoming supply at 11,000 volts 25 cycle is transformed by a bank of single-phase transformers (Fig. 9) to six-phase low voltage and delivered to a 500 K.W. rotary (Fig. 10), which generates direct current at 500 volts.

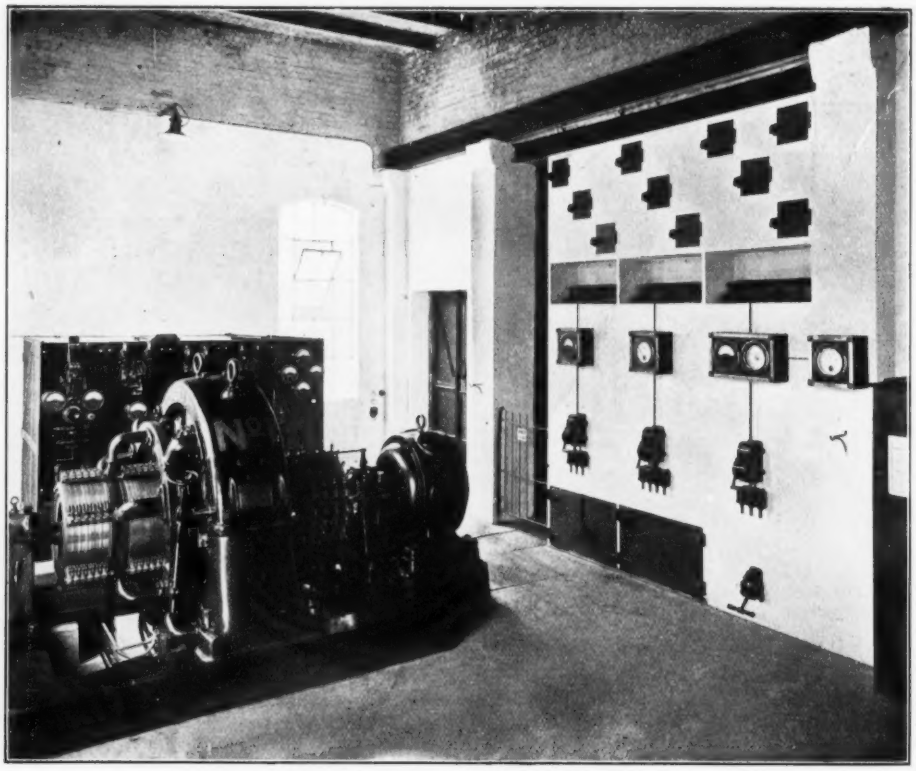


Fig. 10. — View of Rotary House.

The plant illustrated herewith is installed at the Waterloo Tinplate Company's Works, and the machines were built at the Siemens Works, Stafford, which have now passed into the hands of the English Electric Company.

Fuses

By H. W. KEFFORD, A.C.G.I., A.M.I.E.E.

The purpose of this article is first to review the present status of the fuse in electrical lay-outs generally, giving some indications of the lines along which fuse design should be developed, and then to describe some typical apparatus in which fuses of the most modern type are employed.

With regard to future progress, it may be remarked that although the fuse is the simplest and oldest device for the automatic protection of electrical circuits from abnormal currents, its action depends upon a complex interaction of physical laws, the incidence of which may be varied within wide limits by the selection of materials and the disposition of the various parts.

The field now occupied by fuse protection may be divided under the following heads :—

(A). *Generator Protection.*—Fuses are now employed only for the protection of small units working at low or medium pressures, and have been almost entirely displaced by automatic switches for large units and for pressures exceeding 650 volts. Much greater progress has been made in the design of air-break and oil-break automatic switches than in that of fuses, with the result that the automatic switch has come to be looked upon as superior in point of (1) quick replacement, (2) safety and reliability in action. For continuous currents we are limited to the use of the ordinary air-break switch or circuit-breaker which, when operating under heavy overload or short-circuit, is not free from certain risks due to the open arc, and is, moreover, liable to get out of adjustment ; quite apart from the objectionable character of an open arc, it is necessary to fix the position of such a switch in a very definite relation to surrounding apparatus and metal work. A reliable enclosed fuse is not only cheaper and suitable for fixing in the most convenient position, but gives the maximum of safety due to the absence of any exposed arc, freedom from noise when operating, and accuracy of rating within very narrow limits. Finally, a fuse possesses that much sought-for characteristic of an inverse time lag, a property by virtue of which it has repeatedly been called upon to assist its big brother, the automatic switch. Within certain limits, this property can be extended to meet a variety of requirements. It may be of interest to remind the reader that fuses of the enclosed type can be designed to give much larger time lags, except on very heavy overloads, than an open type fuse.

For quick restoration of the circuit, the automatic switch appears at first sight to be pre-eminent, but this is mainly of importance on traction loads, and may be disadvantageous if the fault persists. In many cases, for example on board ship, an arrangement of two or more fuses with a changeover switch would meet every requirement, and would facilitate control over the occurrence of faults, etc.

Attention may now be drawn to the distinction between overload and short-circuit protection and considering generators of large size which are now protected by air-break or oil-break automatic switches, it is possible that a combination of these as overload protectors with fuses to deal with short-circuits may offer several advantages. The two means of protection would probably be arranged in series and the fuse shunted by a limiting resistance or reactance. This combination might be even more applicable at the supply end of feeders.

(B). *Feeder Protection.*—Much of the foregoing applies here also, and no amplification is proposed so far as protection at the supply end of feeders is concerned. There is, however, a wide field for improving the protection of sub-feeders and distributors by the judicious insertion of fuses at certain points. Such a scheme has been adopted with considerable success on at least one system having a very large industrial load which is densely located, and it has been found an effective aid to ensuring continuity of supply and quick localisation of a faulty cable. Fig. 1 shows a protection unit standardized to meet these requirements. At the point where the distributor is teed off, two fuses are inserted in series, with a changeover switch which short-circuits one or the other of them. Normally, the smaller fuse, say, of 100

ampere size, is in circuit ; if a fault occurs of sufficient magnitude to blow the fuse, the changeover switch is operated and a fuse of say, 200 ampere size thrown into circuit, thus giving the fault an opportunity to clear while the smaller fuse is renewed. If necessary, the faulty section can be isolated by means of a switch or link. A similar arrangement could be adopted for high-tension distribution with even greater possibilities of increasing the reliability of supply and limitation of disturbances.

Consider a long-distance transmission line passing near to a number of villages or even isolated farms or factories, to each of which a supply of energy has to be given. The simplest and most economical plan is to use a pole transformer with fuse protection mounted alongside. Services up to 100 K.W. could certainly be dealt with in this manner.

(C). *Consumers' Service Protection.*—For this purpose the fuse holds its own, although circuit-breakers have been tried extensively on some continuous-current power supply systems.

For high-tension services, the automatic oil-switch is largely used, but the future development of electrical supply should create a demand for simpler and more economical protection, and suitable fuses should meet the case for all but the largest installations.

For the protection of consumers' services it is essential that the fuses should be of a thoroughly reliable type, capable of disconnecting the supply promptly and cleanly in the event of a short-circuit, and, as a rule, the greater the capacity of the power station and density of load, the higher the standard to which they will have to conform. Fuses which protect installations within a short radius of a large power station have to withstand very much more onerous conditions than those on similar services at the end of a long feeder. The severity of the short-circuit with which a fuse may have to deal depends upon the kilowatt capacity connected to the feeder and the resistance of the circuit, and in the case of a large supply system this short-circuit current may be very great indeed.

(D). *Power Installation Protection.* — This section applies primarily to the protection of individual motors and lends itself to very full discussion owing to the great variety of the conditions to be met. The most important point to be considered is the time-element or sluggishness of the fuse in relation to the type of motor and the characteristics of the load with which it deals. Taking a number of typical cases, we may first consider a continuous-current motor driving a centrifugal pump or other machine giving a well-defined load which cannot normally exceed a known maximum ; if the head of water is constant no appreciable overload can occur unless a mechanical defect arises, such as a faulty bearing or a choked pipe, and the motor fuses are not called upon to carry any appreciable overload even for a short period. A similar motor operating an ordinary industrial load like a line shaft may be subjected to an overload up to, say, 50 per cent., and will carry the overload without injury according to the makers' rating for a definite time varying inversely with its magnitude. In this case the fuses also must be capable of carrying these overloads, and the ideal time-overload characteristic for such fuses would be parallel to and only slightly above the motor rating curve, the margin being sufficient to allow for variations in the atmospheric temperature ; it is clearly more necessary to allow some margin when selecting the most suitable size of fuse than in the first case considered.

Some of the most difficult cases are those of (*a*) motors driving machines like punches, shears, etc., subject to overloads of a severe character for very short periods; (*b*) motors taking abnormal starting currents as with star-delta starters and when driving machines possessing large inertia or high static friction. In extreme cases of the last kind, a combination of an automatic switch with fuses becomes necessary, the former being set high to deal with the starting period and the fuses giving the necessary protection under normal running conditions, but in most instances under case (*a*) a fuse of suitable time-element will give the protection required. Amongst its many advantages, the enclosed fuse is in general slower in action under all but large overloads and more sensitive to a rapidly increasing excessive overload than a fuse of the open type, and at the same time the design of an enclosed type gives much wider possibilities of control over all the properties which may be called for in a fuse to meet specified conditions.

In view of the importance of the fuse for protecting motors and other medium-current consuming devices, the writer will perhaps be excused for digressing in some detail into the subject of enclosed versus open or protected-type fuses.

The arcing which inevitably attends the operation of any practical device for interrupting

an electric circuit is rightly regarded as an occurrence of great potential capacity for mischief, which must be circumscribed and guarded against with the utmost care. In circumstances where only instructed personnel have to be considered, it is sufficient if the position of the apparatus is such that the arc cannot cause any damage to material or create any risk of accidental injury to the authorised attendants. Immediately, however, such arcing apparatus is placed where people unconversant with its dangers have access, it is fully enclosed, so that the arc can produce no harmful effects outside the enclosure, which must itself be fireproof. The enclosure of switches and circuit-breakers used under such conditions has long been insisted upon, and the risk attendant upon arcing has been further emphasised and guarded against by the prohibition of switchboxes having an open slot for the handle, by the interlocking of the switch handle with the cover of the case, and by the introduction of and demand for switches of the quick-make and quick-break type. So far as present means allow, the danger from arcing in switches and circuit breakers has been guarded against and reduced to a minimum. A similar policy is equally necessary for fuses, in fact the need is greater in this case owing to (*a*) the much wider distribution, (*b*) the automatic operation with heavy overload or short-circuit, (*c*) grouping of several in close proximity to one another, (*d*) the temptation for replacement by unskilled persons, (*e*) the possibility of fusion occurring without its being observed. These appear to be thoroughly practical and weighty inducements for every exertion to be made to limit as far as possible any risk of injury or damage from the arc produced when a fuse blows. The occurrence of the arc we must accept as inevitable; what, then, are the best means available for confining its effects within the smallest boundaries? To ask the question is to formulate an answer. The arc, and hence the fuse wire for its whole length, must be enclosed in fireproof material.

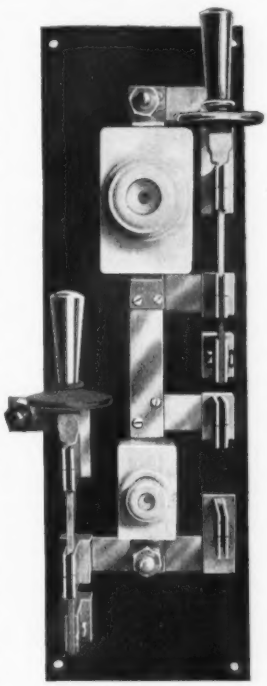


FIG. 1.

No fuse in which the fuse wire is not completely enclosed from end to end in fireproof material is free from danger due to arcing, and the risk which may arise from the scattering of molten or red-hot fuse metal is quite as great and more insidious.

Passing now to the more technical aspect, it may be stated that the essential properties of any fuse are:—

(1). Its capability of opening the circuit cleanly and reliably under any conditions of overload or short-circuit which may arise.

(2). Appropriate sluggishness to meet and follow the overload capacities of the apparatus or material protected.

(3). Safety for handling.

(4). Quickness of replacement.

(5). Safe running temperatures and reasonable energy consumption.

With regard to properties (1), (3), (4) and (5) there is no room for question that a totally-enclosed cartridge fuse is far superior to any type of so-called wire replacement fuse, and the cartridge fuse offers the further important advantage that the replacements are available as self-contained, definitely calibrated interchangeable units. Immunity from arcing and explosive action in a fuse is closely bound up with the mass of fuse metal present and for good operation, particularly at high pressure, it is of great importance to reduce the volume of metal to a minimum. The volume required for a given fusing current depends upon (*a*) the metal adopted, (*b*) the mode of use. For the metals copper, silver, aluminium, zinc and tin the relative volumes required are approximately proportional to 1, 1·5, 3, 8 and 13 respectively, assuming the method of mounting and conditions of use to remain constant. The mode of use, that is to say the degree of protection, type of holder, safe length, etc., has an influence no less marked than that of the metal employed, but a full treatment of this question is beyond the scope of the present article. One broad statement will suffice, namely, that a totally-

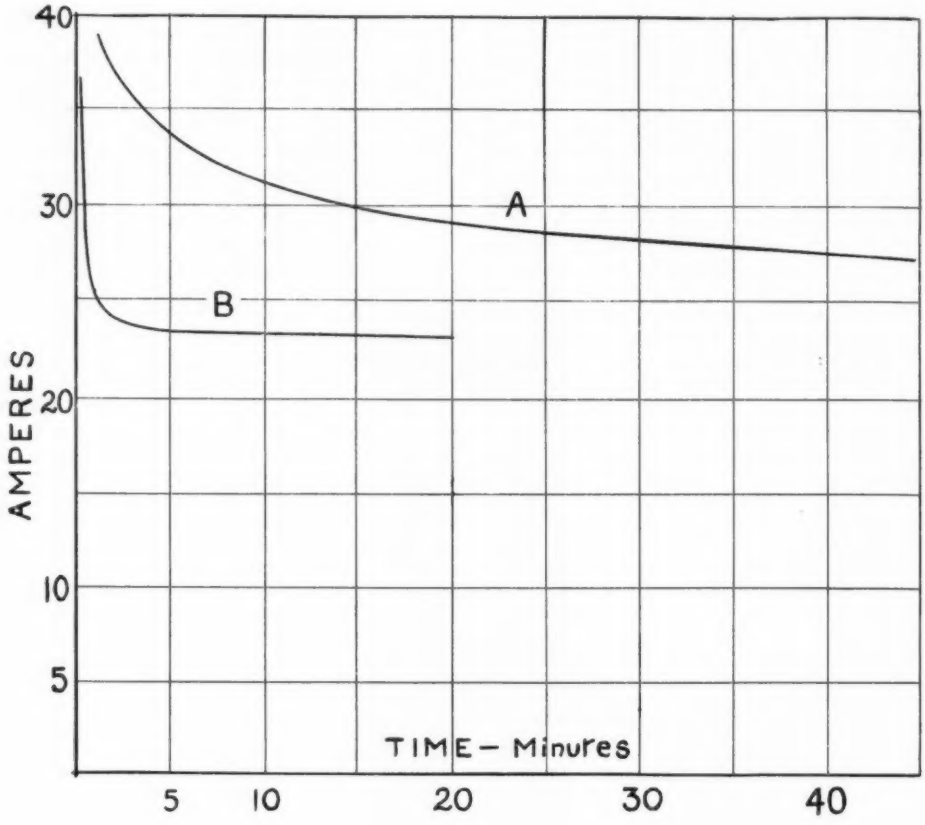


FIG. 2.

enclosed fuse offers the greatest possibility of reducing the mass of metal required to very small proportions, owing to the shorter length of fuse wire which may safely be used for a given pressure and to the greater current density at which the fuse wire must be run by reason of the increased cooling facilities inseparable from this type of fuse as compared with one of the open or protected type. Taking as an example a 500 - volt fuse which will operate in one minute with a current of 25 amperes and will carry 15 amperes continuously, the masses of metal required for (1) a bridge type fuse with tin wire, (2) a totally-enclosed cartridge fuse with silver wire are roughly in the ratio of 115 to 1.

Dealing now with property (2), namely, the sluggishness or time element, we find that in general an open fuse wire is relatively very sensitive to small overloads by reason of its free radiation, whereas an enclosed fuse of the same continuous-carrying capacity will carry for an hour or more an overload of, perhaps, 15 per cent. to 25 per cent., which would cause the open wire to fuse in a minute or less. This is due to the much greater heat capacity of the body of the enclosed fuse and its considerably greater radiation constant or external conductivity. For heavy overloads, however, the enclosed fuse often operates more quickly, owing to the much smaller mass of metal present and the shorter time available in which the containing body can absorb the heat generated. It remains for those most intimately concerned to review the position from the standpoint of the

permissible overloads on apparatus, machinery and cables, and to lay down their requirements with regard to sluggishness ; the manufacturers will then study the best way to fulfil such requirements.

(E). *Lighting Installations.*—In this case the protecting fuses are not required to carry continuously any overload at all but primarily to give protection against short-circuits. The time-element of the fuse may therefore be quite small, and the addition of further lighting points or the use of lamps taking more power should be dealt with by insertion of larger fuses, provided the capacity of the wiring is not overlooked. For lighting work the requirements of safety in operation and handling and quick replacement are of the utmost importance, and, in view of the desirability of providing for replacement by non-technical persons, an enclosed cartridge fuse is the ideal type for this class of circuit.

A few words on the rating of fuses may not be out of place. Commercial fuses of any type are given a nominal current capacity of so many amperes, and in some cases this is supplemented by more or less complete information as to the overload capacity ; for example, cartridge fuses of American manufacture are stated to comply with the regulations of the National Board of Fire Underwriters, and on the Continent the rules of the V.D.E. are usually worked to. In the case of the protected type fuse now so common in this country, a few manufacturers furnish a table of sizes of fuse wire together with the fusing current required for operation in, say, one minute ; with this type, however, the carrying capacity depends to a very great extent upon the surrounding conditions and, indeed, upon the manner in which the wire is

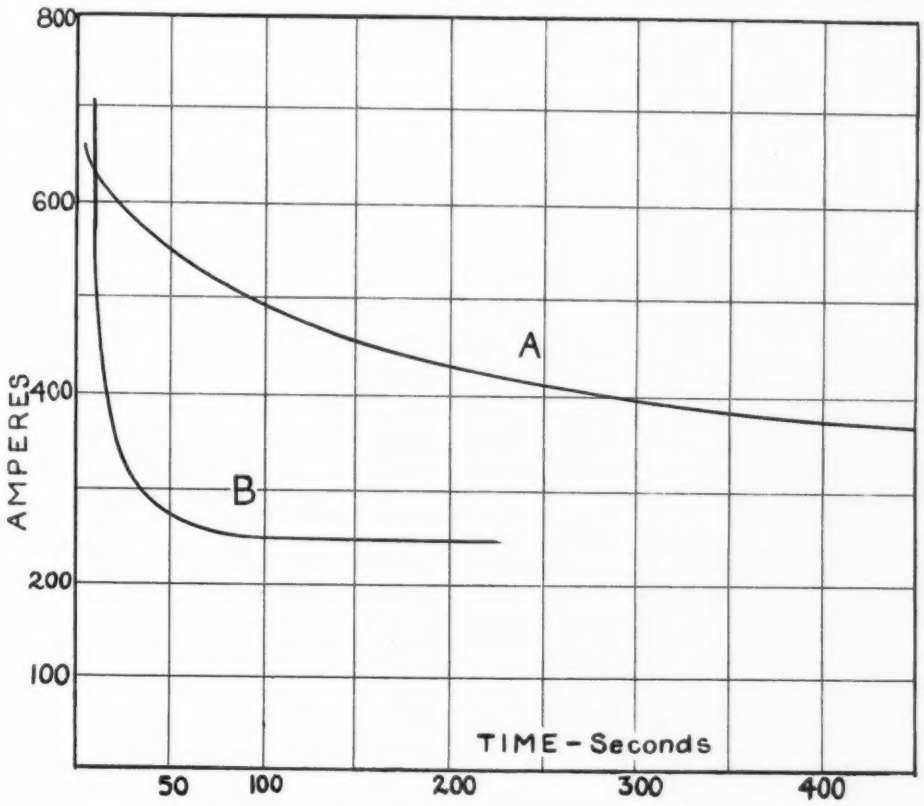


FIG. 3.

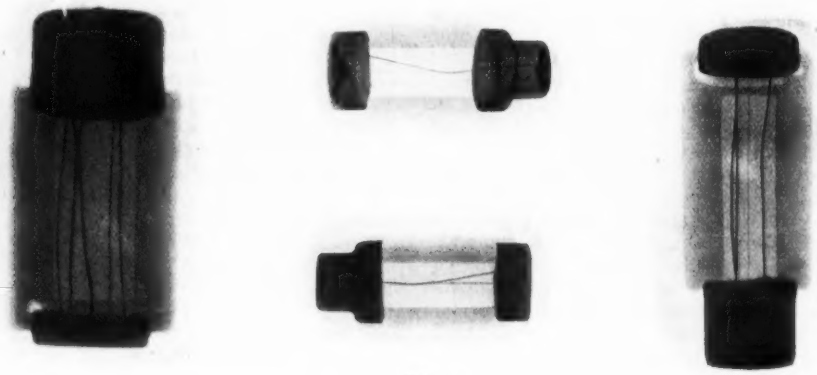


FIG. 4.

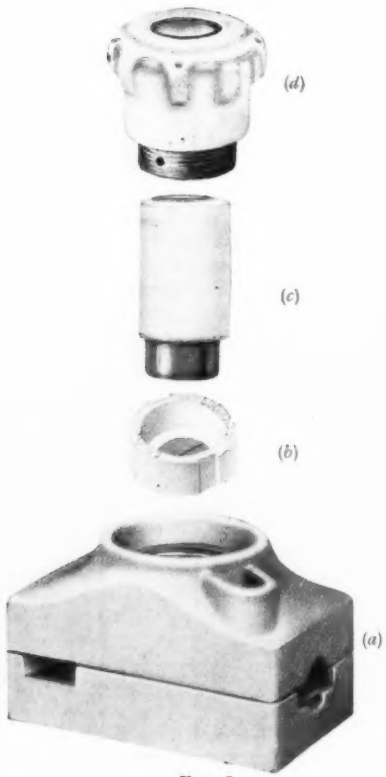


FIG. 5.

inserted. The wire in one case may be in contact for its whole length with the surrounding insulating material, or it may be quite isolated from it, while the passage in which it is placed may be relatively free or, on the other hand, obstructed by the remains of previously used wires, etc. In few cases, however, is information readily available as to the maximum current which a given size of wire fuse will carry continuously when used in the particular fitting; consideration will show that this is an important characteristic quantity, for it defines the overload which the material protected may be constrained to carry continuously. This quantity has been variously named the minimum fusing current, the normal fusing current, and the limiting current; the last name appears to have much to recommend it, since the current value in question is the limiting or boundary value between all values of current which will not produce fusion, however long they may persist, and those values of current which will cause fusion in some finite time. Knowledge of the limiting current of any fuse is of great value, since when taken in conjunction with the rated current and one, or preferably two, points on the time-overload curve, most of the information needed in practice can be deduced with sufficient accuracy. To summarise, we have as the basis of fuse rating the limiting current referred to certain standard conditions of atmospheric temperature, ventilation, and so on; below this is the nominal rated current. If the rated current is chosen, for example, 10 per cent. below the limiting current, the greatest overload which can

indefinitely persist is 11 per cent. above the rated current; similarly, if the rated current is 20 per cent. below the limiting current the maximum continuous overload possible is one of 25 per cent. With regard to the other point or points on the time-overload curve, it is probable that the most generally informative overloads would be 10 per cent. and 25 per cent. above the limiting current, but a more satisfactory plan would be to publish the curve itself between the limits of, say, 10 per cent. and 75 per cent. overload on the limiting current. Taking the two first mentioned percentages, we see that if :

$$\frac{\text{Limiting current}}{\text{Nominal Rated Current}} = a$$

Limiting Current + 10% = $1{\cdot}10a \times$ Nominal Rated Current, or a load of $(110a)$ % on Rated Current.

" " + 25% = $125a \times$ Nominal Rated Current, or a load of $(125a)$ % on Rated Current.

If $a = 1{\cdot}2$ the maximum continuous overload above the rated current is 20 per cent, and the overloads referred to the rated current, which correspond to 10 per cent and 25 per cent. in excess of the limiting current, are 32 per cent. and 50 per cent. respectively. The curves of Figs. 2 and 3 show the wide range in time element which may be obtained for fuses having the same limiting current, in the first case of 23 amps, and in the second case of 250 amps. The relative rapidity of open-type fuses is illustrated very clearly, and it is seen that the greatest time lag obtainable is about 1·5 minutes in one case and 5 minutes in the other.

Any efforts to be made in the direction of standardising the characteristics of the time-overload curves for a complete range of fuses should take fully into account the fact that the injury to apparatus against which protection is sought is primarily injury arising from overheating, and such overheating is subject to similar time-variation laws as those which govern the melting of the protecting fuses. It is therefore not only unnecessary but positively

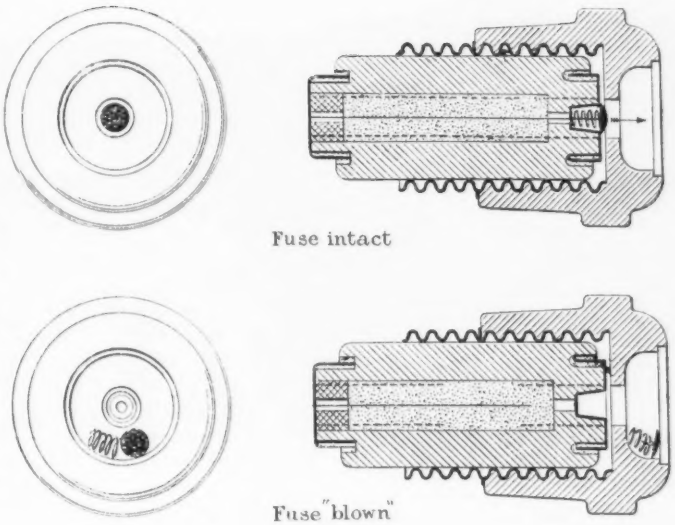


FIG. 6.

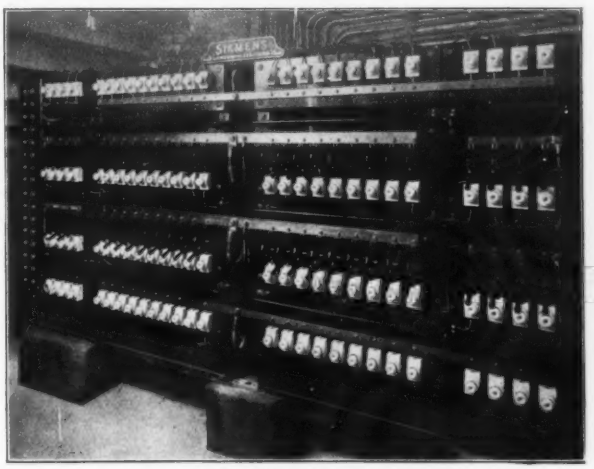


FIG. 7.

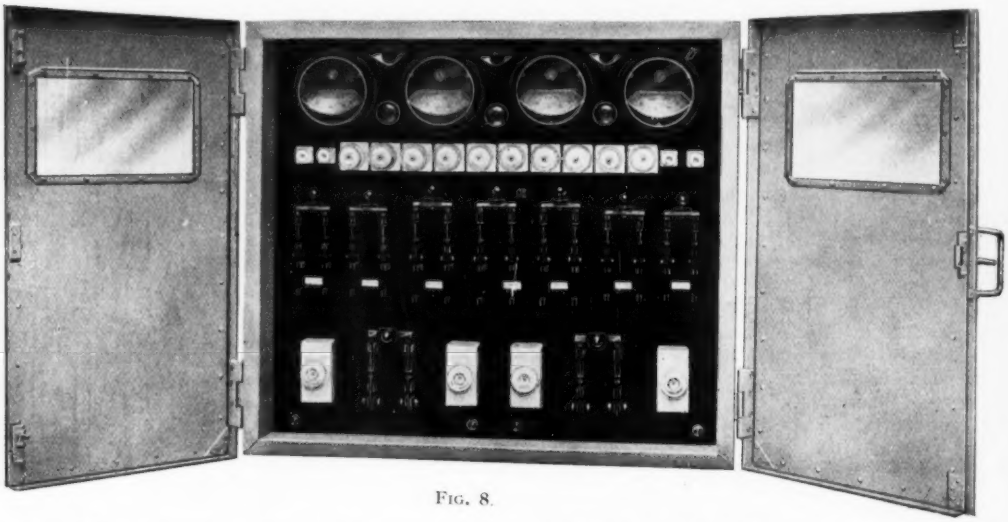


FIG. 8.

harmful to attempt to specify the same degree of sluggishness or time-element in a fuse for say 200 amperes as in one of, say, 20 amperes. The matter is worth much attention, and if taken in hand would materially contribute to the successful development of the fuse as a protective device.

The oldest fuses consisted of a simple bare wire, generally of lead, tin, or a low melting-point alloy, connected between two terminal posts. As the pressure of supply increased, the capacity of circuits became greater, and more attention was paid to safety by fire insurance companies and other authorities, fuse design developed along three broad lines. In this country a link of insulating material, usually porcelain, was introduced for supporting the fuse wire, and later for encasing it. In the United States the Edison fusible plug represented the first attempt towards an enclosed fuse, but the main development was in the direction of enclosed fuses of the fibre tube pattern, while on the Continent enclosed fuses of the porcelain cartridge type became firmly established and were rapidly improved. During the last ten years the enclosed fuse has steadily risen in the favour of progressive and discerning engineers in this country, and this has been in a large measure due to the introduction of the extremely efficient enclosed cartridge fuse which is now well known as the " Zed " fuse.

" Zed " fuses are manufactured at the Stafford Works of the English Electric Company, and the general construction of the fuse bases and cartridges is too well known for a detailed description to be necessary. Fig. 4 is of interest as giving a unique view of the interior of a " Zed " fuse cartridge ; the illustrations are full-size, and show the sub-division of the fusible metal, its short length and the considerable thickness of the walls of the container. The fuse wires are completely sealed in a non-inflammable, non-hygroscopic container of ample mechanical strength, so that all hot metal and arcing phenomena are strictly confined to the small chamber in which the fuse metal is situated.

It should also be noted that the volume of the fuse metal is extremely small in comparison with that used in any open or protected type cut-out, and the very satisfactory behaviour of these fuses under the most severe conditions is largely due to this fact. The reduction of the metal volume is effected by four means, each of which is of some interest. In the first place, the enclosing tube or cartridge body increases the effective radiation of heat from the fuse wire and thus brings about a reduction in the size of wire required for a given fusing current ; secondly, the non-arcing construction of the fuse cartridge permits the terminals to be brought closer together and the length of fuse wire reduced. The third means is that already

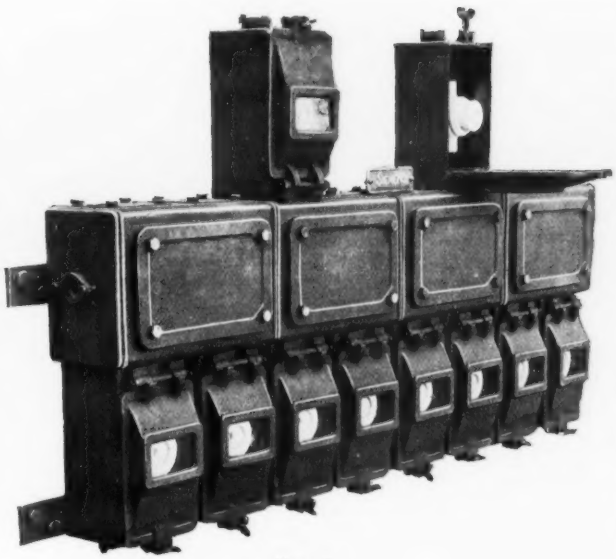


FIG. 9.

mentioned of sub-dividing the fuse wire and thus increasing the ratio of cooling surface to the cross-section or mass of metal, while the last, but not least, important means is the selection of a fuse metal of high conductivity, namely, pure silver. The use of this metal not only contributes largely to the safe and clean operation of the fuse, but gives in addition the valuable advantage of being practically immune from corrosion under all ordinary working conditions.

The porcelain body of the cartridge has walls of sufficient strength to resist any explosive pressure which might be produced, and the terminal caps at the top and bottom are not only well secured by cement, but any tendency for them to be forced off by internal pressure is completely resisted by the cartridge being clamped firmly in the fuse fitting between the lower contact at one end and the screw cap at the other.

Fig. 5 shows the four principal parts of a complete fuse, namely, (*a*) the screw cap by means of which the cartridge is held and inserted in the fitting, (*b*) the cartridge, (*c*) the gauge ring or intermediate lower contact by means of which it is possible to restrict to any given size the largest cartridge which can be inserted in a fitting, (*d*) the fuse base.

One of the most interesting and useful features of this fuse is the Indicating Device which is fitted in a recess in the top contact; this consists of a small coloured metal disc held in place by a fine wire of resistance material which runs through the cartridge parallel to and in parallel with the fuse wires themselves. Fig. 6 shows the construction and mode of operation of the Indicator. A spiral spring of minute proportions is compressed under the disc when the retaining wire is pulled

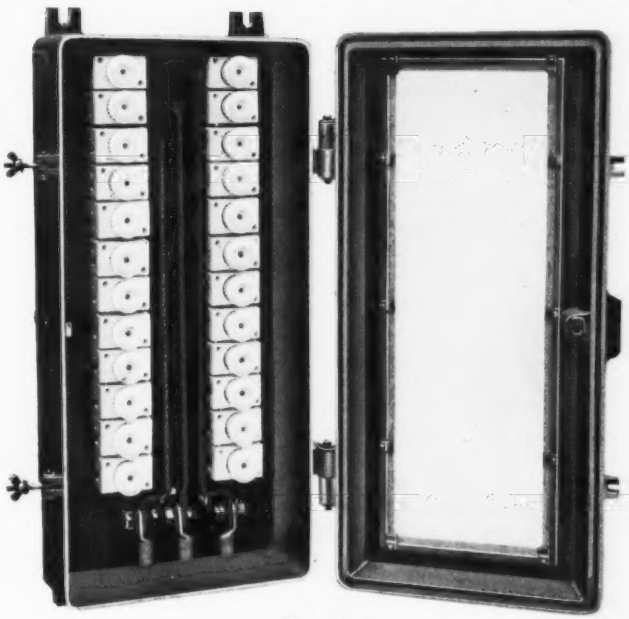


FIG. 10.

taut during manufacture. As will be seen, the blowing of the fuse will result in the indicator disc falling into the screw cap in the manner shown. Another small but very convenient detail is that the indicator disc is coloured distinctively for each standard current throughout the range, thus a cartridge for 10 amperes 250 volts has a red disc, so also has a 10-ampere cartridge for 500 volts or 750 volts; cartridges for 20 amperes have blue discs, and so on. The normal current and voltage are marked on the top cap or terminal plate of every cartridge, and the variation in voltage is emphasized by the length of the cartridge, which varies from about 1 in. overall for 250 volts to about 2½ ins. for 750 volts.

The illustrations published herewith show typical examples of distribution apparatus in which the fuses are of the "Zed" totally enclosed pattern. Fig. 7 shows a main distribution board for controlling the circuits in a large public building. The board is fixed in a confined space, so that all connections are arranged on the front, and the back of the slate panels is within a short distance of the wall. On the left will be seen a vertical slate panel drilled to form a receptacle for spare use cartridges. In Fig. 8 is shown an iron-cased main switchboard for controlling the generators and feeders on a torpedo-boat destroyer; it will be noticed that the adoption of an enclosed fuse has enabled the board to be compressed into very small dimensions. All the connections are arranged at the back of the slate panel, and the iron case is provided with doors at the rear to give access for connecting up. The small wall type distribution board shown in Fig. 9 is built up on the unit principle, and provides for the control of ten 100–200 ampere distributors on a 650-volt power system with earthed negative; the board is completely weatherproof and provides for extension to a further six ways. The bus-bars are supported on porcelain insulators within the central bus-bar chambers.

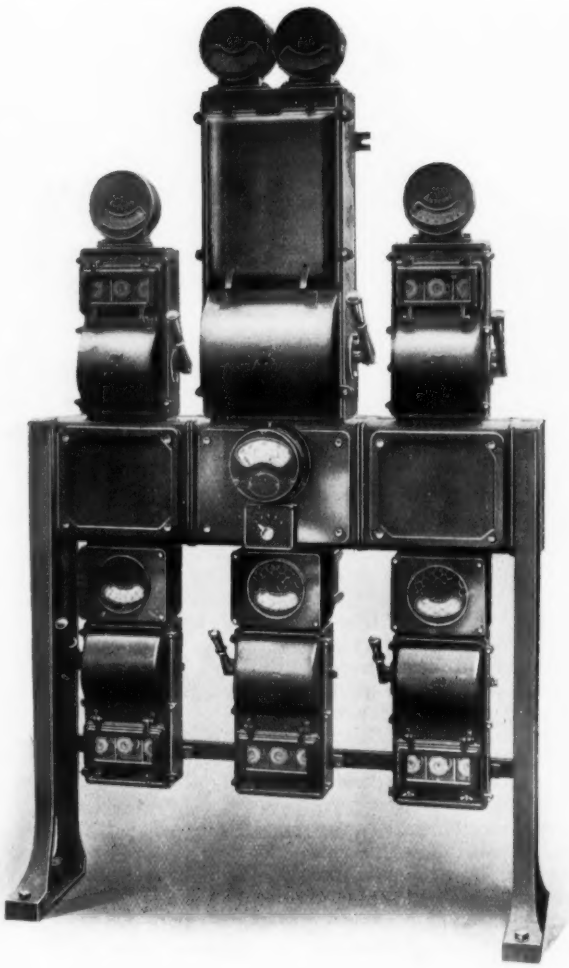


FIG. 11.

Fig. 10 illustrates a three-phase distribution board for the control of eight motor circuits, and

exemplifies the very compact arrangement which is possible when a reliable enclosed fuse is adopted. One of the most essential requirements in a board for this class of service is ease of connecting up, and this is provided for by arranging the three fuses for each circuit adjacent to one another, so that four of the circuits enter on the right and four on the left of the cast iron case. The mains enter at the bottom and run straight into the respective cable sockets, which are protected by a substantial cover of insulating material, omitted in the photograph to show the arrangement of the main terminals. Three-phase boards built on these lines have proved eminently satisfactory under varying conditions of service, and are standardised for circuits requiring up to 150 amperes and 650 volts.

Fig. 11 shows a good example of a main switch and fuse distribution board of the unit type for floor mounting. This class of board has many advantages for industrial work, and the employment of " Zed " enclosed fuses materially contributes to safety in operation and economy in space. The board is entirely ironclad and weatherproof throughout; the fuses are accessible through the small hinged glazed lid seen at the top of each switch and fuse box, and in the large sizes this lid is interlocked with the switch handle. All live metal in the switch-boxes is mounted upon vitreous porcelain and a separate porcelain base is used for each pole. For similar boards of larger bus-bar capacity, the main switch may be of the iron-clad oil-break type as shown in the centre of the board illustrated in Fig. 12.

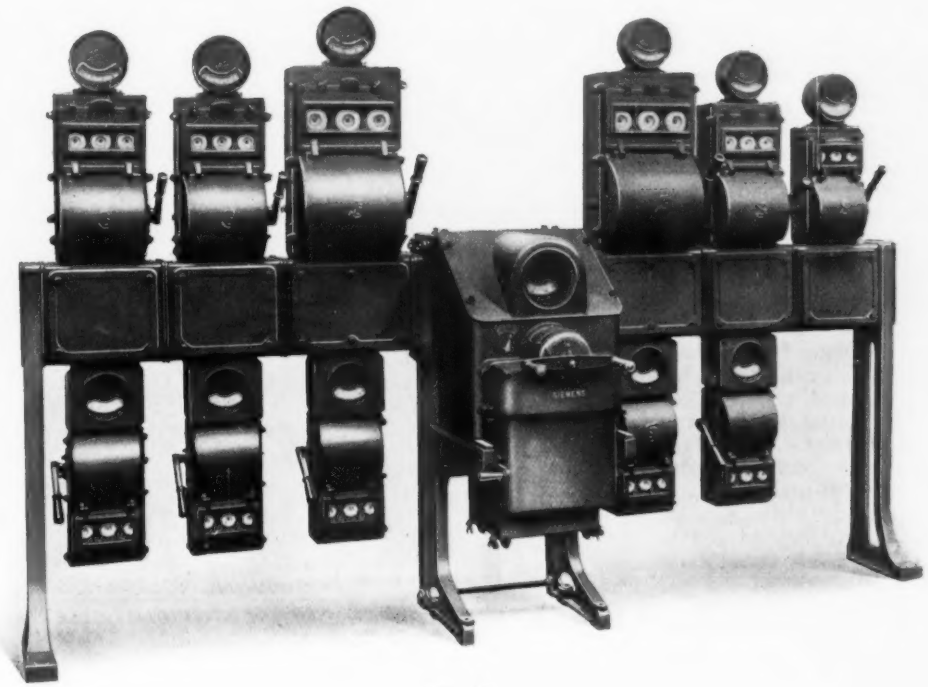


FIG. 12.

The Cooling of Water in a Canal

By L. C. Kemp, B.Sc. (Eng.), A.M.Inst.C.E.

(A Description of a recent Series of Experiments carried out at the Lero Road Power Station, Leicester.)

At the present time the subject of heat dispersal in canals is of particular interest in view of the number of large power stations which are being erected on canal sites.

In such cases the cooling of the circulating water will be carried out mainly with natural draught towers, but it will be advantageous, especially in the winter months, to utilise whatever assistance the canal is able to give, and so improve the average vacuum and station economy.

The Lero Road Power Station of the Corporation of Leicester is situated on the banks of a canal, upon which it relies entirely for the cooling of circulating water for the condensers, and for this reason was chosen as a suitable site for investigation.

The station has approximately 9,500 K.W. of plant installed, and provides power for the tramways and industrial undertakings in the district up to 8,000–9,000 K.W. maximum daily demand, with an average daily load factor of approximately 40·5 per cent.

The inlet and outlet circulating water ducts are separated by less than 200 yards, yet, by reason of the various factors described later, sufficient cooling is effected to operate the station satisfactorily.

Fig. 1

The experiments in question were carried out primarily to examine in a qualitative sense the conditions assisting the dispersal of heat which made this result possible, whilst it was also endeavoured to establish Heat Gradient Charts

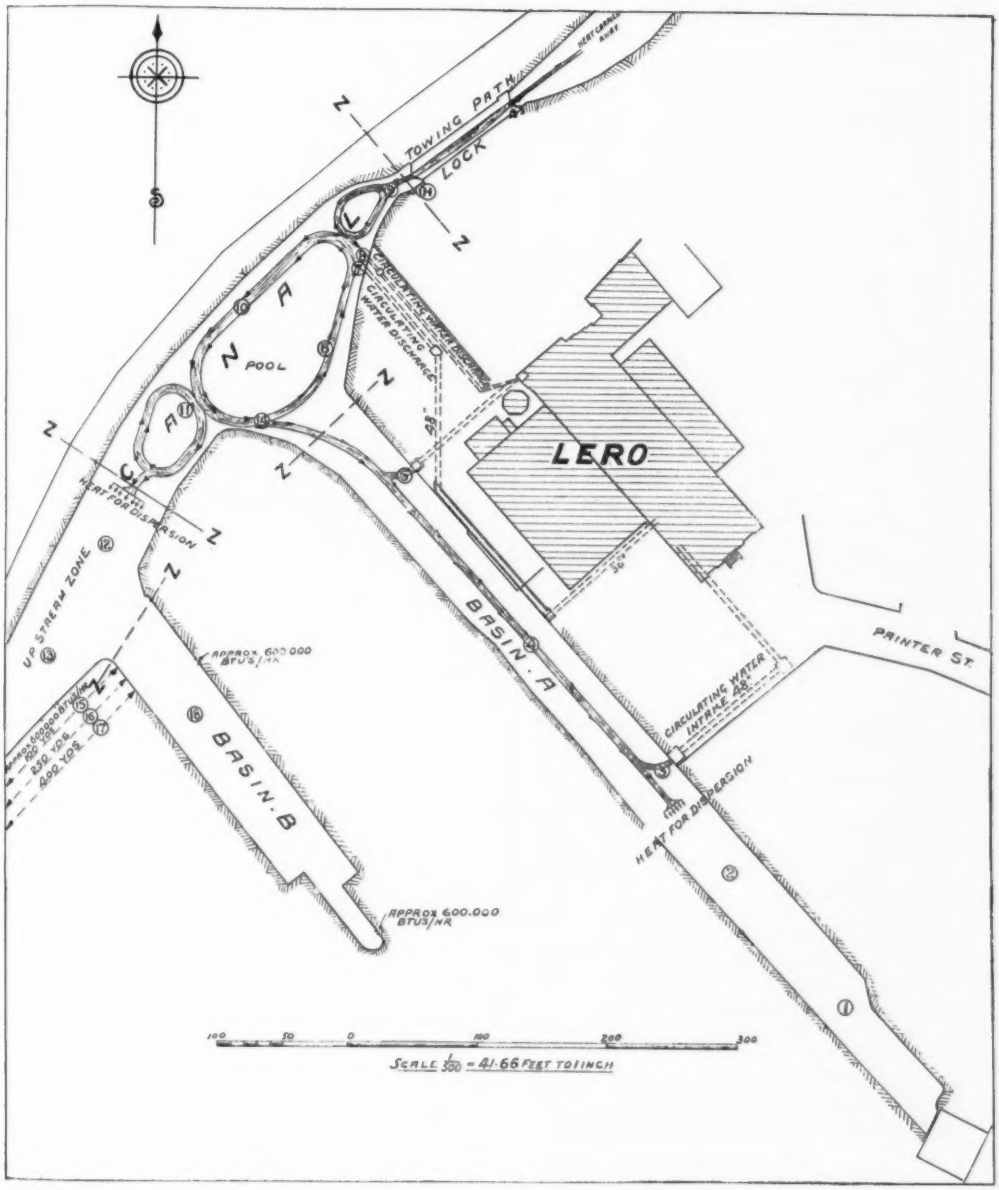

TOWING PATH
LOCK
POOL
LERO
BASIN A
BASIN B
PRINTER ST.
UP STREAM ZONE
APPROX 600 000 BTUS/HR
APPROX 600.000 BTUS/HR
CIRCULATING WATER INTAKE 48"
HEAT FOR DISPERSION
SCALE 1/500 = 41·66 FEET TO 1 INCH

FIG. 2.

and an approximate Dispersal Factor which would be of value as a basis in determining the probable performance of proposed new power stations for similar sites.

Site Particulars and preliminary investigation of the Water Currents in the canal.

The position of the power station and a plan of its site are shown on the drawings (Fig. 1) and (Fig. 2), and it will be seen from Fig. 2 that the circulating water discharged from the station enters into the canal at Points 7 and 8, and that the suction culverts draw from Basin "A" at Points 5 and 3.

It will here be noted that the power station plant is divided into turbine and reciprocating machinery, the former using circulating system 3 to 7, and the latter using the system 5 to 8, also that

(*a*) the distance between Points 8 and 5 is approximately 200 feet, and

(*b*) the distance between Points 7 and 3 is approximately 500 feet.

In addition to a very considerable heat flow from the Lero Road Power House at Points 7 and 8 (Fig. 2), an examination of the canal banks and enquiries at neighbouring works showed that small additional quantities of heat entered the canal at points as follows :—

Figs. 1 and 2 Pts. marked.	Circulating Water discharge from :	B.T.U.'s per hour.
V (Corah's Works)	80 B.H.P. @ 20 lbs./B.H.P.	$1{\cdot}6\times10^6$
W (Gas Works)	30 B.H.P. @ " "	$\cdot6\times10^6$
X	Similar to W	$\cdot6\times10^6$
Y	Slightly less than W	$\cdot5\times10^6$

On the day of the tests there was a slight flow down the stream, this being shown by a flow of water about 1½ ins. deep over the lock gate sills (8 ft. aggregate width), and during the actual time of the tests three boats were locked through, but this did not appear to have any effect on the average water quantity flowing over the gates.

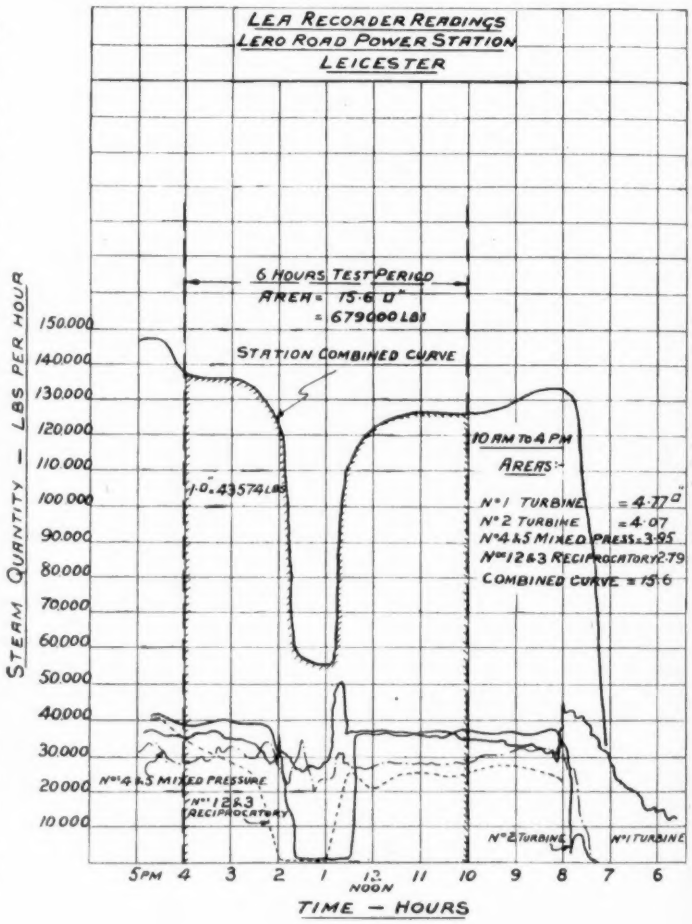


FIG. 3.

In order to gain knowledge of the conditions in the canal before deciding on the exact course of the thermal experiments, a preliminary investigation was carried out to define the nature and direction of the water currents.

A series of floats, made from ⅜ ins. wooden sticks 30 ins. long, loaded at one end, were carefully dropped at chosen points across the

discharge stream at Points 7 and 8. All the floats passed across the stream towards the opposite bank, and then divided in direction, two passing to the right and three to the left, three others which ran aground and retired from usefulness not being considered.

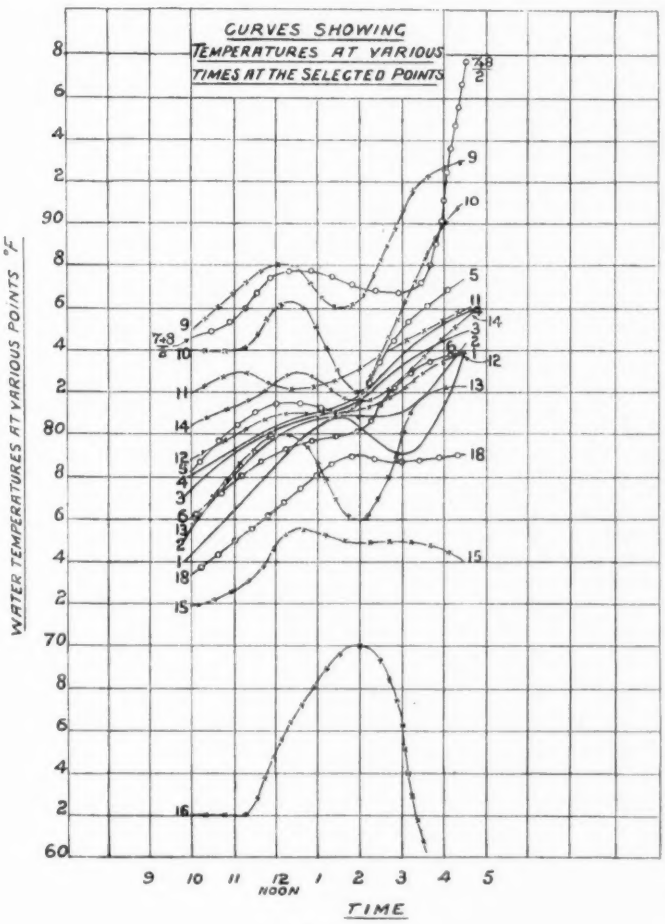

CURVES SHOWING
TEMPERATURES AT VARIOUS
TIMES AT THE SELECTED POINTS
WATER TEMPERATURES AT VARIOUS POINTS °F
TIME
9 10 11 12 NOON 1 2 3 4 5

FIG. 4.

Of the two which went to the right, one was carried in an eddy back into the discharge stream, the other passed over the lock ; of the three which went to the left, one was carried in a large eddy back into the discharge stream, another broke from the eddy passing on towards the suction point, another broke off up-stream and settled in a small induced eddy. A fourth float dropped well inside the eddy, located by Points 6, 10 and 14, continued to circle slowly.

These currents, which were hotter than the rest of the water, are shown diagrammatically in Fig. 2.

DESCRIPTION OF TEST.

In order to determine the nature of the cooling taking place and to obtain a heat account for the cooling system, it was decided that the scope of the measurements to be taken should embrace the following considerations :—

(*a*) The heat quantity entering the canal from various sources.

(*b*) Temperature of the canal surface in the area affected by the heat currents.

(*c*) Atmospheric conditions.

(*d*) Heat carried away through the lock.

(*e*) Heat stored or released from the bulk of the water quantity affected, due to difference in average temperature before and after the test.

(*f*) Cooling effect of cold river water entering the system to provide make-up for the water evaporated.

Measurements were taken at frequent intervals between 9 a.m. and 5 p.m., and for the test period the six hours between 10 a.m. and 4 p.m. were chosen.

(*a*) *Heat quantity entering the canal from various sources.*

Half-hourly readings were taken in the engine house to provide a record of :—

(1) The loads on the various power units, and

(2) The inlet and outlet temperatures of the circulating water.

Three Lea Recording instruments at the same time registered the total steam consumed by the turbine and reciprocator units.

Fig. 3 shows the Lea Recorder diagrams of the turbines plotted to a common scale and combined to provide a station curve (comparable to a load curve) of steam consumption.

It will be noted from Fig. 3 that the load dropped considerably for about an hour between 12.30 and 2 p.m.

The area of the combined curve provides a measure of the total steam condensed over any chosen period, and thus also of the total heat transmitted to the condenser circulating water. That is to say :—

$$\left.\begin{array}{l}\text{Total heat in B.T.U.'s}\\ \text{discharged into the canal}\\ \text{at Points 7 and 8 during}\\ \text{the test period ... ...}\end{array}\right\} = \left\{\begin{array}{l}\text{Area of combined}\\ \text{curve in lbs. of steam}\\ \text{condensed between}\\ \text{10 a.m. and 4 p.m.}\end{array}\right\} \times 1050 \text{ B.T.U's per lb.}$$

b) Temperature of canal surface in the area affected by the heat currents.

To determine the surface temperature variations in the canal and to obtain figures for the calculation of a dispersal factor, a number of selected points on the canal system were visited in a punt throughout the day, and a record kept of the temperatures and the times at which the readings were taken. These points, Nos. 1 to 18, are marked on the drawing (Fig. 2).

Appendix I gives a list of the readings of time and temperature which were taken, and Fig. 4 shows the same figures plotted in separate curves for each point.

The object in producing Fig. 4 has been that such a series of curves allows the temperature at the various points to be considered simultaneously as set out in the curves of Figs. 5 and 6, whereas the actual readings for the various points were taken consecutively.

(c) Atmospheric Conditions.

Periodical measurements of the wet and dry bulb thermometer were taken in order to define the hygrometric state of the atmosphere. These are given in Appendix I. The average wind velocity was estimated at 20 miles per hour.

(d) Heat carried away through the lock.

Periodical measurements were taken to record the head of water flowing over the lock gate sills, and a note made of the times when boats passed through the lock. The readings taken are summarised in Appendix II, which describes also the calculations to determine the total quantity of hot water passing away through the lock during the 6-hours' test.

This water enters the area near Point 16 at a temperature of 47°F., and leaves it at the lock at the increased temperature of Point 9.

Thus :—

$$\left.\begin{array}{l}\text{Heat flow}\\ \text{over lock}\end{array}\right\} = \left\{\begin{array}{l}\text{Total water quantity}\\ \text{in lbs.}\end{array}\right\} \times \left\{\begin{array}{l}\text{Temp. at Pt. (9)}\\ -47^{\circ}\text{F.}\end{array}\right\}$$

(e) Heat stored or released from the bulk of the water quantity affected, due to difference in average temperature before and after the test.

During the test the temperature of water showed a nett increase at all points, and in order to gauge the quantity of heat thus stored it was decided to measure approximately the total volume of the water in the area affected. To do this soundings were taken at selected sections of the basins, pool and stream.

As the temperature variations in certain portions of the area would be greater than in others, it was decided to divide the total area into zones over which the temperature variations were not large. These zones are indicated in Fig. 2 by the boundary lines ZZ.

Then :—

$$\left.\begin{array}{l}\text{Total heat stored}\\ \text{in the four zones.}\end{array}\right\} = \Sigma \left\{\begin{array}{l}\text{Wt. of water}\\ \text{in each zone}\end{array}\right\} \times \left\{\begin{array}{l}\text{Nett rise in}\\ \text{temperature}\end{array}\right\}$$

Appendix III gives the areas, average depths and volumes of the selected zones.

The nett rises in temperature (*vide* Appendix IV) between 10 a.m. and 4 p.m. have been obtained from an average of the temperature rises recorded in Fig. 4.

(f) Cooling effect of cold river water entering the system to provide make-up for the water evaporated.

The quantity of make-up water which will flow into the area from the river will depend on the amount of surface evaporation. This, in turn, will be proportionate to the total amount of cooling from the canal surfaces, and for the purpose of our calculation the proportion will be represented by approximately 80 per cent.; thus, taking X to represent the total heat quantity dispersed from the water surface and through the earth, the make-up water quantity will be approximately represented by the factor ·80 X divided by the latent heat of steam.

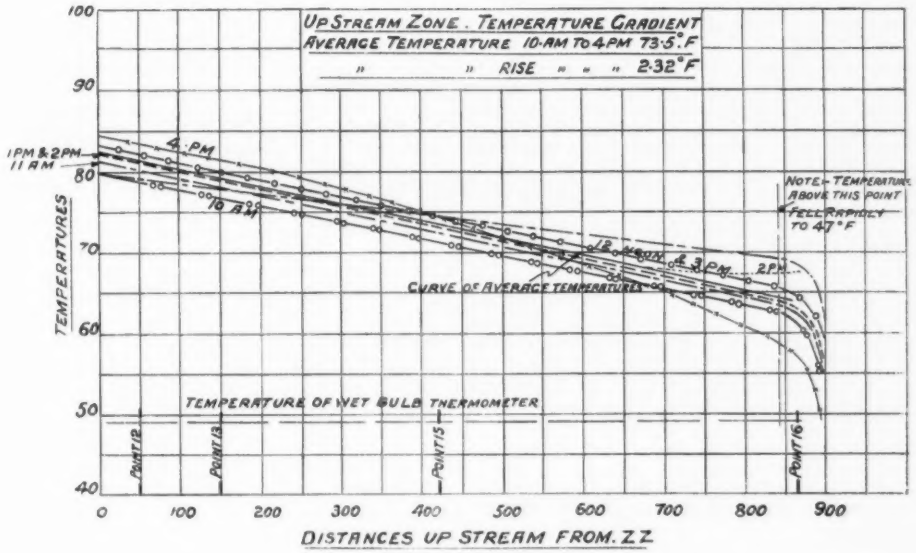

UP STREAM ZONE. TEMPERATURE GRADIENT
AVERAGE TEMPERATURE 10 AM TO 4 PM 73·5° F
" " RISE " " " 2·32° F
1 PM & 2 PM
11 AM
4 PM
10 A.M.
12 NOON
3 PM
2 PM
NOTE:- TEMPERATURE ABOVE THIS POINT FELL RAPIDLY TO 47° F
CURVE OF AVERAGE TEMPERATURES
TEMPERATURES
TEMPERATURE OF WET BULB THERMOMETER
POINT 2
POINT 3
POINT 5
POINT 6
100
90
80
70
60
50
40
0
100
200
300
400
500
600
700
800
900
DISTANCES UP STREAM FROM Z Z

FIG. 5.

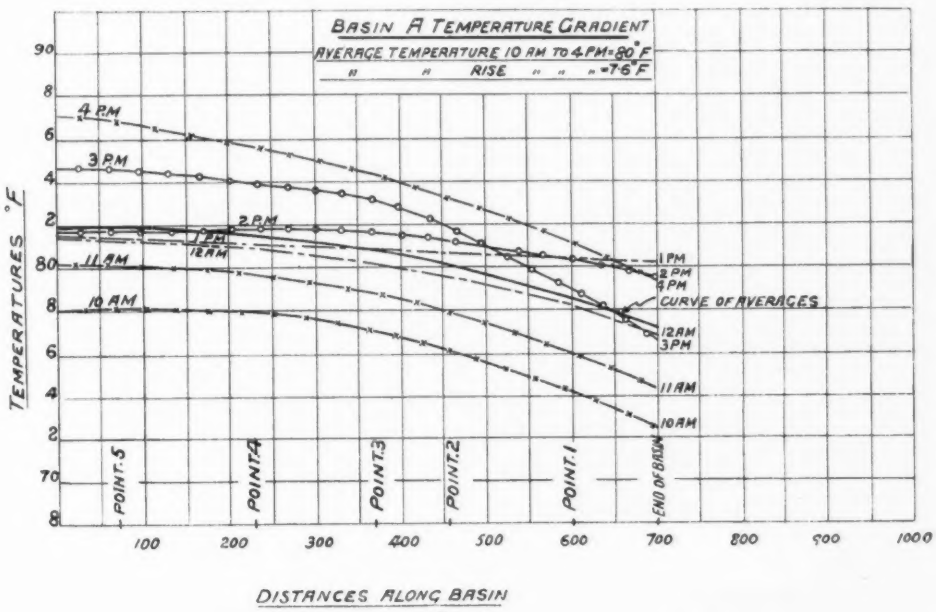

BASIN A TEMPERATURE GRADIENT
AVERAGE TEMPERATURE 10 AM TO 4 PM = 80° F
" " RISE " " " = 7·6° F
TEMPERATURES °F
4 PM
3 PM
2 PM
1 PM
12 AM
11 AM
10 AM
1 PM
2 PM
4 PM
CURVE OF AVERAGES
12 AM
3 PM
11 AM
10 AM
POINT 5
POINT 4
POINT 3
POINT 2
POINT 1
END OF BASIN
100
200
300
400
500
600
700
800
900
1000
DISTANCES ALONG BASIN

FIG. 6.

The heat absorbed by the make-up water entering the zone will be measured by its rise in temperature from the cold river water to the average temperature of the cooling zone.

Summary of Results.

Collecting the information contained in the Appendices, a summary of the test results may be obtained as follows :—

(1) *Heat received into the Canal during the test period.*

			B.T.U's.	Ref. Fig. 3
(*a*)	From Lero Power Station	$= 679000 \times 1050 =$	713×10^6	
(*b*)	Point V (Corah's Works)	$= 160000 \times 5 =$	8×10^6	
(*c*)	,, W (Gas Works)	$= 600000 \times 5 =$	3×10^6	
(*d*)	,, X	$= 600000 \times 5 =$	3×10^6	
(*e*)	,, Y	$= 500000 \times 5 =$	$2{\cdot}5 \times 10^6$	
		Total $=$	$729{\cdot}5 \times 10^6$	

(2) *Heat dispersed and absorbed into the Canal during the test period.*

			B.T.U's.	
(*a*)	Passing away through the lock		$135{\cdot}3 \times 10^6$	App. II
(*b*)	By rise in temperature of bulk of water.			Apps. III, IV, & V
	Basin A	$= 7{\cdot}6°F. \times 108000 \times 62{\cdot}5 =$	$51{\cdot}4 \times 10^6$	
	Pool	$= 5{\cdot}58 \times 98000 \times 62{\cdot}5 =$	$34{\cdot}2 \times 10^6$	
	Basin B	$= 5{\cdot}6 \times 40000 \times 62{\cdot}5 =$	$14{\cdot}0 \times 10^6$	
	Up-stream Zone	$= 2{\cdot}32 \times 144000 \times 62{\cdot}5 =$	$20{\cdot}9 \times 10^6$	
(*c*)	Heat dispersed from water surface	$=$	.. ..	X
(*d*)	By cooling from make-up water $= \frac{{\cdot}80X}{965}(78{\cdot}3-47$	$=$	.. ..	$0{\cdot}0259X$
		Total ..		$255{\cdot}8 \times 10^6 + 1{\cdot}0259X$

(3) *Determination of Heat quantity dispersed from water surface.*

Heat received = Heat dispersed and absorbed.

$$729{\cdot}5 \times 10^6 = 255{\cdot}8 \times 10^6 + 1{\cdot}0259\,X$$

Thus—

$$X = \frac{(729{\cdot}5 - 255{\cdot}8) \times 10^6}{1{\cdot}0259}$$

Heat dispersed from canal surfaces

$$= \frac{473{\cdot}7 \times 10^6}{1{\cdot}0259}$$

$$= 461{\cdot}8 \times 10^6 \text{ B.T.U's.}$$

And

Heat absorbed by cold make-up water $= {\cdot}0259\,X$

$$= 11{\cdot}9 \times 10^6 \text{ B.T.U's.}$$

(4) *Heat Account.*

Collecting the preceding results, the following heat balance sheet is obtained :—

Heat dispersed or absorbed. B.T.U's.		Heat received. B.T.U's.	
Carried away over lock	$135{\cdot}3\times10^6$	Lero Power Station	713×10^6
By rise in temperature of bulk of water	$120{\cdot}5\times10^6$	Other sources	$16{\cdot}5\times10^6$
By heat given to make-up water entering the up-stream zone	$11{\cdot}9\times10^6$		
Balance dispersed from water surface and by conductivity through earth ..	$461{\cdot}8\times10^6$		
	$729{\cdot}5\times10^6$		$729{\cdot}5\times10^6$

(5) *Determination of Approximate Dispersal Factor.*

The balance of heat dispersed from the canal will be mainly due to heat lost by evaporation from the water surface, but will include also radiation and conduction into the air, and conduction into the earth through the bed of the canal.

Let ρ = dispersal factor of the day in B.T.U's per sq. ft. of water per hour per inch Hg. difference in the vapour pressures corresponding to the water surface temperature and the atmospheric wet bulb temperature.

Average wet bulb temperature reading (*Vide* App. I) = 49°F.

Corresponding Vapour Pressure = ·334″ Hg.

Total Heat Quantity X dispersed from the canal surface $= \rho\,\Sigma$ { (Area of each zone in sq. ft.) × (V.P. Hg. corresponding to average surface temperature − V.P. corresponding to atmospheric wet bulb) × (Time in hours).

$461{\cdot}8\times10^6$ = $31200\rho \times (1{\cdot}04-{\cdot}334) \times 6$ (Basin A)

plus $23900\rho \times (1{\cdot}15-{\cdot}334) \times 6$ (Pool)

plus $13000\rho \times ({\cdot}93-{\cdot}334) \times 6$ (Basin B)

plus $42400\rho \times ({\cdot}82-{\cdot}334) \times 6$ (Up-stream zone)

$= (132000+117000+46500+123500)\,\rho$

$= 419000\rho$

Dispersal factor $\rho = \dfrac{461{\cdot}8\times10^6}{419{,}000} = 1{,}100$ B.T.U.'s/sq. ft./hr./inch Hg. difference in the vapour pressures corresponding to water surface temperature and atmospheric wet bulb temperature.

This factor represents the rate of cooling actually occurring during the test period and, strictly speaking, is only applicable to other sites when the atmospheric and geological conditions are similar. It will be useful, however, in conjunction with the heat gradient charts as a foundation on which to base an estimate of the degree of assistance which may be expected under particular conditions at other canal sites.

Throughout the test a wind estimated at 20 miles per hour was scouring the water surface, and for Still Air Dispersal, therefore, the factor should be considerably reduced—approximately to one-fifth of the above value.

The investigation demonstrates strikingly that cooling is effected largely outside the circuit followed by the water between the circulating water discharge and intake. The distance between these may be relatively small, but the heat will leave the circuit followed by the water and flow for a considerable distance along the canal, thus increasing the cooling zone more or less adequately. In this case the heat actually flowed up-stream for nearly a quarter of a mile against a slow current.

From the temperature gradients in the up-stream zone (Fig. 5) an interesting estimate may be made of the rate of flow of surface heat in still water.

It was noted throughout the test that readings of temperature taken in the neighbourhood of and above Point 16 fell with extreme rapidity to the temperature of 47°F. of the incoming river water.

By careful measurement, the velocity of the stream at this point was found to be approximately 2·5 ft. per minute, and it is considered that a probable explanation of the phenomenon is that the rate of heat flow was here balanced by the rate of surface water flow down-stream.

The measurements of surface temperature were taken at a depth of approximately 8″, and the motion of the water surface down-stream, taken by means of floats, would represent the velocity of an average depth of about 10″.

From the curves of average temperatures in Fig. 5 it will be seen that the rapid fall took place between the temperatures of 64°F. and 47°F., so that assuming that the rate of heat flow is directly proportionate to the temperature difference, an approximate figure of 0·14 ft./min. is obtained to represent the rate of heat flow per °F. difference in temperature.

In conclusion, it is hoped that these notes, incomplete in many respects as they undoubtedly are, will be found to contain information of interest to those concerned with cooling and condensing problems, and suggest lines for the further investigation of a subject upon which very little has been said or written in the past few years.

The author desires to convey his grateful thanks to Mr. T. R. Smith, the Chief Engineer and Manager of the Leicester Corporation Electricity Department, for the ready assistance given him in the prosecution of the foregoing experiments.

APPENDIX I.

Record of Temperatures taken at Various Points on the Canal and Basins.

Period under consideration—9 a.m. to 5 p.m., Tuesday, January 3rd, 1920.

Point No.	Time.	Temp.	Time.	Temp.	Time.	Temp.	Time.	Temp.	Time.	Temp.	Time.	Temp.
1	9.50	74	11.4	76.5	11.45	78	1.38	81	3.04	79	4.38	84
2	9.51	75	11.5	78	11.46	79.5	1.38	81	3.06	81	4.37	84.5
3	9.52	77	11.5	79	11.47	80	1.40	81	3.08	83½	4.36	85
4	9.54	78	11.6	79.2	11.48	80	1.41	81	3.10	84	4.36	86
5	9.56	78	11.7	80·5	11.52	81·5	1.43	81	3.10	85	4.35	86·5
6	10.00	76	11.10	78	11.53	79	1.45	80	3.15	83	4.34	84
7	10.1	79	11.11	78	11.54	82·5	1.46	82	3.20	81	4.30	95
8	10.2	90	11.11	93	11.55	92	1.47	83	3.20	93	4.30	101
9	10.3	85	11.12	87	11.55	88	1.48	86	3.25	92	4.30	93
10	10.6	84	11.15	84	12.00	86	1.50	82	3.30	88	4.27	91
11	10.7	82	11.18	83	12.00	82	1.52	83	3.30	85	4.25	86
12	10.8	79	11.18	80	12.01	81	1.54	81	3.35	83	4.25	84
13	10.10	76	11.20	79	12.02	80	1.55	76	3.35	82½	4.25	82
14	..	..	11.40	82	12.20	83	2.25	81·5	..	..	4.35	86
15	10.15	72	11.22	73	12.03	75	1.57	73	3.40	75	4.25	74
16	10.20	62	11.25	62	12.05	65	1.59	70	3.45	48	4.20	52
17	..	..	11.30	47	..	..	2.00	47	3.50	47	4.15	47
18	..	..	10.30	74	..	..	2.10	79	..	..	4.25	79
Wet Bulb	11.00	48·5	11.40	49	12.00	49	2.20	49	..	..	4.30	50
Dry Bulb	11.00	49·5	11.40	50	12.00	49·5	2.20	53	..	..	..	..
H.	10.5	1½″	11.15	1¾″	12.00	1½″	1.49	1½″	3.25	1¾″	4.35	2½″

Note. 1. H = The head of water immediately over the lock gate sill. The effective width of the sill is approximately 8 ft.

2. Dimensions of Lock.—Area 60′ × 14′. Drop in levels 4′ 6″.

3. Times at which boats were locked through—10.30, 11.30, 11.45 and 4.20.

APPENDIX II.

Flow of Water and Heat Through the Lock.

(1) *Water Quantity.*

The head of water flowing over the sill of the lock (8 ft. wide) was measured at various times throughout the test, and the readings H will be found tabulated in Appendix (I).

For a flat crested weir—

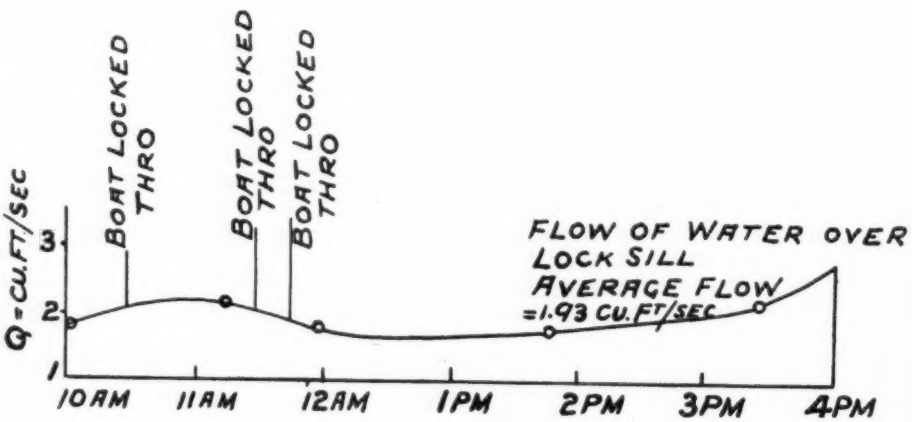
$$Q = C.L.H.^{\frac{3}{2}} \quad \text{(Lea \& Bazin)}$$

Where H = Still water head above sill.
C = 2·66 (Bazin)
$H = \frac{2}{3}H'$

Thus in terms of our readings of H

$$Q = 2{\cdot}66 \times L \times \tfrac{2}{3}H' \sqrt{\tfrac{2}{3}H'}$$
$$= 39{\cdot}1\ H'$$
(where L = 8′)

Thus—							
Time	10.5 a.m.	11.15	12.0	1.49 p.m.	3.25	4.35
H′ inches	1½	1¾	1½	1½	1¾	2½
Q cu. ft./sec.	1·73	2·18	1·73	1·73	2·18	3·72



From the graph, average flow = 1·93 cu. ft./second.
Total flow over lock sill (six hours) = 41,600 cu. ft..... (*a*)
Dimensions of lock = 60′ × 14′ × 4′ 6″ drop in water levels
Total volume let through the lock during six hours' test = 3 locking operations
= 11,340 cu. ft..... (*b*)

that is to say—

Total water passed through lock during test (*a*) + (*b*) = 41,600 + 11,340
= 52,940 cu. ft.

(2) *Heat Quantity.*

Average temperature at Pt. (9), obtained from curve in Fig. 4 = 87·8°F.
Average temperature of water above Point (16) = 47°F.

Therefore
Total heat carried away
through lock during the test = $(87{\cdot}8 - 47) \times 52940 \times 62{\cdot}5$
= 135×10^6 B.T.U's.

APPENDIX III.

(1) *Area of water affected by the heat flow from Lero Power Station.*

The temperature gradient up-stream (Fig. 5) shows that the heat travels to a point approximately 10 yards below Point 16. All water below this point, as far as the lock gates, is raised in temperature by the heat flow from the condensers, and is thus responsible for this absorption and dispersion of the heat.

For convenience in making calculations, this area is divided into zones, over which the temperature variation is not large, the boundaries of the zones being represented on the chart by the lines ZZ.

The areas and average depths of these zones are given below, the average depths being obtained from soundings (see Appendix V) :—

	Water Surface. sq. ft.	Average Depth ft.
Basin "A"	31,200	3·46
Pool	23,900	4·10
Basin "B"	13,000	3·10
Up-stream to within 10 yards of Point 16	42,400	3·40

(2) *Volume of water affected.*

		cu. ft.
Volume Basin "A"	= 3·46×31,200 =	108,000
„ Pool	= 4·10×23,900 =	98,000
„ Basin "B"	= 3·10×13,000 =	40,000
„ Up-stream to within 10 yards of Point 16 ..	= 3·40×42,400 =	144,000
		390,000

APPENDIX IV.

Average Canal Temperatures and Temperature Rises.

(A). *The average temperature in each zone.*

From the temperature curves in Fig. 4 and the temperature gradients plotted for Basin "A" (Fig. 6) and the up-stream zone (Fig. 5), the following average temperatures over the period of the test were calculated for each zone :—

Basin "A"	80·5°F.
Pool	83·6°F.
Basin "B"	77·1°F.
Up-stream zone..	73·5°F.

To calculate the average temperature for the whole of the water contained in the four zones, the total heat quantities contained in each of the zones were added together and the sum divided by the total weight of water (*vide* Appendix III), i.e.

$$\text{Average temperature} = \frac{\Sigma\ (\text{Weight of water in each zone multiplied by its temperature.})}{\text{Total weight of water in the four zones.}}$$

Average temperature = 108,000×62·5×80·5
plus 98,000×62·5×83·6
plus 40,000×62·5×77·1
plus 144,000×62·5×73·5
divided by 390,000×62·5
= 3,056,000 / 390,000
= 78·3°F.

(B). *Average rise of temperature in each zone.*

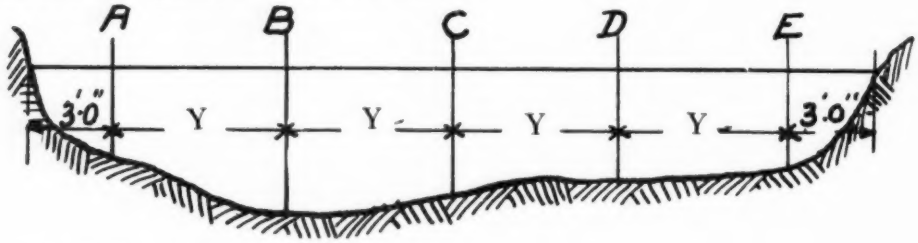
From Figs. 4, 5 and 6 average rises in temperature in the various zones between 10 a.m. and 4 p.m. were obtained as follows :—

Basin "A"	7·6° F.
Pool	5·58°F.
Basin "B"	5·6° F.
Up-stream	2·32°F.

APPENDIX V.

Record of the Soundings taken to determine the average depths in the four zones.

As indicated in the sketch below, which represents a typical section across the canal, soundings were taken at points A and E, 3 ft. from the banks of the stream, and at points B, C and D, equally spaced between points A and E.



The following results were obtained :—

Section at point (Fig. 2).	Depth in ft.					Dimension Y (in ft.).
	A.	B.	C.	D.	E.	
1	1	3	3	3½	3½	10
2	3	3½	3½	3½	3½	10
3	4	4	4	4	3½	10
4	3	4	4	4	3	10
5	3	4	4	4	3	10
7 & 8	4	6	6	5	3	12
9	6	7	7	7	6	6
10 to 6	3	4½	4	4	2	24
11	1	4	4½	3	1	15
13	3	4	4½	4	2½	15
16	2	3	5	4	2	10

The average depths are given in Appendix III.

HEAD OFFICE:

Queen's House, Kingsway, London, W.C. 2.

BRANCH OFFICES IN THE UNITED KINGDOM.

Birmingham	Central House, New Street.
Bradford	Phœnix Works, Thornbury.
Cardiff	89, St. Mary Street.
Glasgow	Baltic Chambers, 40, Wellington Street.
Liverpool	16b, Queen Insurance Buildings, 10, Dale Street.
Manchester	196, Deansgate.
Newcastle	64-68, Collingwood Buildings
Sheffield	Foster's Buildings, 22, High Street.

BRANCH OFFICES ABROAD.

Argentine	Balcarce 278, Buenos Ayres.
Brazil	46, Avenida Rio Branco, Rio de Janeiro.
Canada	Transportation Building, Montreal.
India	Clive Buildings, 8, Clive Street, Calcutta.
India	Rampart Row, Fort, Bombay.
India	Smith's Corner, Mount Road, Madras.
Japan	3, Itchome, Uchisaiwaicho, Kojimachi-Ku, Tokyo.
New Zealand	Dominion Farmer's Institute, Featherston St., Wellington.
South Africa	45a, St. George's Street, Capetown.
Straits Settlements	1, 2, 6 & 9, Winchester House, Singapore.

ASSOCIATES ABROAD.

Australia	The English Electric Company of Australia, Limited, 77, King Street, Sydney, N.S.W.
Belgium	Les Constructions Electriques de Belgique, 23, Rue de la Regence, Brussels.
China	Messrs. Jardine, Matheson & Company, Limited, Engineering Department, 8a, Yuen-Ming-Yuen Road, Shanghai.
France	Les Constructions Electriques de France, 19, Rue Louis le Grand, Paris.

Published by

THE
ENGLISH ELECTRIC COMPANY,
LIMITED

Queen's House, Kingsway,

London, W.C. 2

Works:

Coventry, Preston, Bradford,
Stafford, Rugby

Printed for the Proprietors by
Industrial Publicity Service, Ltd.,
4-7 Red Lion Court London, E.C.4